AUG 16 1929

Vol. XII, No. 4 *PSYCHOLOGICAL REVIEW PUBLICATIONS* AUGUST, 1929

Journal of Experimental Psychology

EDITED BY
MADISON BENTLEY, CORNELL UNIVERSITY

HOWARD C. WARREN, PRINCETON UNIVERSITY (*Review*)
RAYMOND DODGE, YALE UNIVERSITY (*Monographs*)
S. W. FERNBERGER, UNIVERSITY OF PENNSYLVANIA (*Bulletin*)
WALTER S. HUNTER, CLARK UNIVERSITY (*Index*)
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PUBLISHED BI-MONTHLY
FOR THE AMERICAN PSYCHOLOGICAL ASSOCIATION
BY THE PSYCHOLOGICAL REVIEW COMPANY
PRINCE AND LEMON STS., LANCASTER, PA.
AND PRINCETON, N. J.

Entered as second-class matter, July 1, 1920, at the post-office at Lancaster, Pa.

Psychological Review Publications

of the American Psychological Association

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PSYCHOLOGICAL REVIEW COMPANY
PRINCETON, N. J. OFFICE

Journal of
Experimental Psychology

VOL. XII, No. 4 AUGUST, 1929

OCULAR MOVEMENTS AND THE PERCEPTION OF TIME

BY J. P. GUILFORD[1]

University of Nebraska

The phenomenon to be described concerns the momentary resting appearance of a revolving wheel in linear movement. The writer first observed that the wheels of a passing motor car were very irregular in their movement, proceeding by alternate stops and starts. Revolving at such a rate the wheel should present a blurred appearance, with a complete mixture of the color of the spoke and of the open spaces. This is the usual result when the car is traveling about twenty miles an hour. But if the eyes follow the hub of the moving wheel, the spokes will occasionally flash out in complete detail for a moment, the whole wheel appearing stationary. At times the car itself seems to pause in its forward motion along with the wheel; but more frequently the car appears to glide on as if sliding silently ahead upon stationary wheels. In both cases the observer experiences a strong feeling pattern. When the car pauses it is best described as a heightened tension, as if one met a resistance in the otherwise smooth-flowing train of processes; but when the car glides on a stationary wheel there is a more empathic feeling of moving forward under resistance and a smooth, gliding impression in which the raucous squeak of brakes and the sliding, tearing noise of tires on pavement are conspicuous by their absence.

At first a theory based upon eye-movements seemed quite plausible. It is well known that the eyes do not follow a

[1] From the psychological laboratory of the University of Kansas.

stimulus with steady sweeping movements, but by successive jerks. Could it not be that the eyes, in shifting their fixation, have a speed of movement which is comparable to that of the advancing spokes, so that the net result is a stationary stimulation upon the retina and a phenomenal stationary wheel? If this were true, only one side of the wheel should momentarily flash out as stationary, since on only one side does the wheel move in the same direction as the eyes. This was contrary to all the writer's observations. In almost every case the spokes on all sides of the wheel flashed out together. We might, of course, explain this fact by the laws of completion of 'good' configurations, but another possibility then occurred to the writer, a theory not based upon eye-movements.

It was noticed that the stationary flashes at times came very rhythmically. This was true especially if a wheel could be fixated and followed without interruption for a longer period of time. It was also observed by counting the number of flashes that the period between them was from 0.5 to 1.0 sec and probably nearer the former estimate. This immediately suggested the results which have been obtained from the extensive work upon the estimation of short intervals of time wherein it was found that the interval about 0.6 sec is most correctly judged. Could it be that these phenomena are related? Is our whole time experience based upon a rhythm of this period and does time phenomenally flow at a non-uniform rate, proceeding by starts and stops? And is this responsible for the stationary phases in the turning wheels? This could be true, of course, only if our time experience is restricted to focal consciousness.

The eye-movement theory can be tested readily by registering the behavior of the eyes during the phenomenon. This is what the writer proceeded to do. It is an easy matter to set up in the laboratory a rotating wheel with spokes, but not so easy to produce the linear translation of that wheel comparable to that of a motor car on the street. A wheel with the rotation alone was made in order to see whether it gave the same phenomenon without the linear movement and

the consequent pursuit movements of the eyes. The wheel was constructed from a black cardboard disk 25 cm in diameter, with a white center 6 cm across, and sixteen white spokes each 1.2 cm in width. This disk was placed upon a motor whose speed could be controlled by means of a rheostat. The optimal speed for producing the phenomenon differs for different observers, but lies in the region of speeds at which flicker ceases and color mixture begins. When one fixates any point upon this disk the usual phenomenon occurs. The writer can see no essential difference between the two, and what differences do exist can be readily attributed to the difference of fixation and to the pursuit movements of the eyes in the one case and not in the other. These differences will be mentioned later.

The three observers in the experiments were Mr. Edwin Newman, assistant in psychology, Mr. Kenneth Braly, graduate student, and the writer.

The disk was set up before the *O* at a distance of 100 cm on a level with his eyes. The room was dark except for a light which was hidden from *O* but which directly illuminated the disk. The light on a circuit of six volts was furnished by a bulb of the type which is used in the headlight of motor cars. An illumination with direct current is necessary because the pulsating light from an alternating current gives a stroboscopic effect upon the disk which interferes with observation of the phenomenon in question.

First note descriptive protocols from the *O*s to see more exactly what the phenomenon is under these conditions.

> Obs. N. I got the spokes very definitely. Occasionally I got things like lightning flashes, light gray bars against a dark background. When I winked I saw all the spokes very clearly all the way around; it seems to stop dead still.
>
> Obs. B. I did not see more than about eight of the entire number (of spokes).
>
> I could see more spokes this time but they were more grayish. When they stop they are moving forward usually, but once or twice they moved backwards.

The writer has verified these descriptions of the disk. Unlike the wheel upon the advancing motor car, only a few spokes are usually seen at one time, and these few appear on different sides of the disk at different times. Another differ-

ence was that the flashes were never rhythmical on the disk. All *O*s were agreed upon this. The rhythmical flashes are therefore conditioned by the linear motion and probably, more specifically, by pursuit movements of the eyes.

Under the laboratory conditions it seemed quite apparent that eye-movements had much to do with the phenomenon. In following the wheels of a motor car no eye-movements coincident with the stationary flashes could be observed, whereas with the rotating disk such eye-movements were easily noticed. They could be felt in the form of pressures or they could be observed visually as shifts of fixation. Voluntary eye-movements invariably gave flashes, and the side of the disk most affected was the side which moved in the same direction as the eyes. N's report that every wink produced a flash (and this can be easily verified) is also an indication since the eyes move during a wink. So perfect seemed this roughly observed correlation that the writer ventured to predict that the disk could be used in the future for detecting all eye-movements. If so, this would constitute a technique widely applicable and very simple in comparison with the photographic technique of Dodge and others.

The protocols of the *O*s appear to favor the eye-movement theory in every way.

> Obs. N. A number of times when I found my eyes moving quite a bit near the periphery of the wheel, I would get the flashes.
>
> Obs. B. I would relax my effort to fixate and then make a renewed effort and it was then that I noticed the spokes.

B's earlier report of slow movement of the spokes in the same or in the opposite direction could be explained by the fact that the eyes were moving slower or faster than the disk.

Before recording eye-movements during the phenomenon by means of the photographic technique,[2] a method of recording simultaneously the pauses observed by *O* had to be devised. This was accomplished by means of a flashlight which threw a pin-point image upon the photographic film beside the pin-point image of the eye. The flashlight was in

[2] The technique was virtually the same as that described by the writer in Fluctuations of attention with weak visual stimuli, *Amer. J. Psychol.*, 1927, 38, 557 ff.

circuit with a key by which *O* reported immediately each flash of the spokes. Some of the flashes came so close together in time that *O* could not report them separately. In that case he reported them by groups of two, or even three, by a corresponding number of dots with the key. After some practice, when *O* was sure he could report all the flashes fairly accurately with his key, photographic records were made.

A glance at the photographic record is enough to convince one of the relation which we expected to find. But closer inspection of the records shows that the association of flashes with eye-movements is not perfect. There are flashes reported when no outstanding eye-movement, other than the usual tremor or tonic adjustment, appears in the record; and conversely, there are noticeable phasic movements with no corresponding report of a flash of the spokes.

In order to test the amount of agreement, the flashes were counted and the number of these with and without corresponding eye-movements noted. Likewise, the number of phasic eye-movements were counted with and without corresponding reports of flashes. The results, in terms of percents and their probable errors, are as follows:

	Flashes accompanied by eye-movements		Eye-movements accompanied by reports of flashes	
Obs.	Percent	p. e.	Percent	p. e.
N	96	.026	62	.053
B	85	.022	35	.020
G	83	.034	80	.035

Thus from 83 to 96 percent of the flashes reported occur along with eye-movements. How can we account for the remaining number which do not? There is the possibility, of course, that *O* may make a false report with his key; but surely this could not be true in as much as 17 percent of the cases. It may be that his report was very much delayed and so would not be counted as correlated with an eye-movement. One *O* did report in his protocol that there was, in a few instances, a lag of about a half-second in his reaction with the key. One might fall back

upon the theory of innervation, that an actual phasic movement is unnecessary. B reports that the flashes came when he made a renewed effort to fixate, which may mean merely a heightened tonicity of the eye muscles. Our eye-movement theory, however, calls for an actual shift of fixation which shall make the image of the disk stationary upon the retina. It may be that with further practice in reporting under the conditions of the experiment, an *O* would increase the correspondence of reported flashes and eye-movements to one hundred percent. The results thus far lead us to expect it.

But granting a hundred percent correlation between the two, can we use the flashes to give us a reliable record of eye-movements? The other column of the table gives us an answer which is doubtful, if not in the negative. The highest correspondence is 80 percent, but the lowest is only 35 percent. N reports in a protocol, however, that he refrained from reporting all flashes when he knew that his general fixation had shifted away from the central region of the disk to the peripheral part. His 62 percent would be materially higher if all the flashes which he saw had been reported. It might be that practice, again, would increase the efficiency of this method of reporting eye-movements, but even so, there are other serious objections against it as a technique to be used during other visual phenomena. The chief objection is that it puts too great a burden upon the observer to report upon two distinct phenomena at one and the same time. One might use the method to detect eye-movements which are suspected at some critical moment, *e.g.* during the fluctuation of a weak visual stimulus; but, if the present results are indicative, the reliability of a statistical study based upon such reports would not be very high. In this experiment *O*'s attention was given to reporting the flashes alone. In observing another phenomenon at the same time he would be required to work under divided attention.

Aside from these considerations, the phenomenon has some interesting ramifications. If we restrict our observation to the phenomenology of it, we have a good example of the distortion of time. This distortion has two possible interpre-

tations depending upon whether our time experience is focal or marginal. Assuming that the course of experiential time is limited to the sphere of the revolving wheel as we give our attention to it, or to the whole motor car as a larger unit comes into the focus of consciousness, we have an alternate stopping and starting of time. We literally 'freeze' a portion of time into a stationary mass. But if we assume that the experience of time goes on as a substrate or a part of the margin or ground upon which the focal phenomenon occurs, the result is a distortion of another sort. When the revolving wheel stops, the stationary impression of it, which should be fleeting if it kept pace with the groundal duration, is prolonged until its duration is multiplied several times. This exaggeration of time may be very great under normal, everyday conditions. A student, who has also observed independently the illusion of the revolving wheel, insists that upon several occasions he has seen a flying rifle bullet 'frozen' in midair. According to the one interpretation, then, we have a kind of 'freezing' or negation of duration, and according to the other we have an exaggeration or prolongation of time.

If we go beyond the phenomenology of the matter to its physiological and stimulating conditions, we find a basis for either interpretation. The stationary flashes are due to stationary images upon a moving retina. If our whole time experience is bound up with the object of attention, in this case the wheel, then time momentarily ceases. This might imply, however, that when any stationary object gains the focus of consciousness while the eyes are motionless, the effect, the negation of time, would be the same. Perhaps this is so. As a matter of fact, no object can maintain the focus unchangingly for more than a moment, nor can the eyes be fixated and unchanging for any longer period of time —probably the two conditions are really but one—so that our interpretation is not so absurd as it may sound.

If the time experience is not restricted to the focal experience, or even if it is rather a constant attribute of the marginal consciousness, then the eye-movements have produced a *local* rather than a *general* distortion of time. This is a more likely interpretation and one which observation best

satisfies, for other experiences of the moment (the movement of the motor car itself, of other objects in the visual field, or the walking of *O* himself) all exist in a time sequence of their own, a time sequence and a durative ground which form a basis of comparison for the spoke phenomenon. The experience of time, as well as the experience of space, quality, and form, seems to satisfy the configural criterion of a figure-ground structure. In this connection let it be recalled that the motor car itself is at times drawn into the prolongation of time; it stops along with the wheels. Further observations are needed to determine the precise conditions for this inclusion, but the writer believes that it occurs when the motor car is included in the 'figure' or as a part of the object of observation, and that, as the wheel alone is singled out for observation, it alone suffers in the distorted time effect.

The connection of the distortion of time with muscular contraction and with movement of the retina suggests another interesting interpretation. Have we not here a case of relativity, analogous to Einstein's relativity in physics? Here is an instance of the prolongation of time along the line of eye-movement. For such an eye, the *moving* wheel does not exist; the time element has been altered. This case may be sheer analogy to physical relativity, but nevertheless it is an interesting one. It demonstrates the dependence of time experience upon the adjustment of sense organs, and, since this adjustment is a muscular affair, upon muscular contraction. A consideration of all such correlations between phenomenal duration and muscular response might lead to some enlightening laws of phenomenal time.[3]

(Manuscript received October 9, 1928)

[3] Since this manuscript was written several other observers have reported similar phenomena, all of them in *Science* for 1928 (Harry S. Gradle, p. 404; Paul F. Gaehr, p. 567; and R. M. Packard, p. 568). In Gradle's report the propeller of an airplane furnished the stimulus. The phenomenon was easier to obtain in indirect vision and with distant accommodation. Gaehr described the 'spoke illusion' and offers the theory that all our time experience is 'quantized.' C. E. Ferree (*Science*, 1928, 68, 645) suggests the eye-movement theory which has been upheld by the results of this study. He suggests that the illusion is easier to get in indirect vision because the limen of fusion is higher there than in direct vision. The illusion is enhanced by distant accommodation because this means a larger pupil, a more intense stimulus, and again, a higher limen of fusion.

ELECTRICAL AND CIRCULATORY RESPONSES TO BRIEF SENSORY AND IDEATIONAL STIMULI

BY CHESTER W. DARROW

Institute for Juvenile Research, Chicago, Illinois [1]

The numerous attempts of psychologists, inspired by Wundt's tridimensional theory of feelings and by James's and Lange's theory of emotion, to find bodily activities corresponding to the psychologicals tates reported by the subject have given conflicting results of doubtful interpretation. These attempts have, however, shown a fairly consistent relation between definite physiological activities and certain aspects of the stimulating conditions which preceded, and it is with such a relation that this paper is chiefly concerned.[2] In this study, the immediate reaction to a sensory situation for which no cognitive activity is required is compared with the reaction to a symbolic sensory situation in which cognitive or other acquired associative activities are essential to produce the typical physiological effect.

This material was accumulated at the Illinois Institute for Juvenile Research during the year 1927 while perfecting apparatus and determining satisfactory methods of stimulation for another study. Seventy persons, most of whom at one time or another were associated with the staff of the Institute, served as subjects. Due to technical difficulties, such as imperfections in control and defects in registration, data from only about half this number are presented in this article. The galvanometer and photokymograph used were loaned from his personal laboratory equipment by Dr. Herman Adler.

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[1] Studies from the Institute for Juvenile Research, Herman M. Adler, M.D., Director, Series B, No. 131. Special appreciation should be expressed to Dr. K. S. Lashley, Dr. Harvey Carr, Dr. Herman Adler, Dr. L. L. Thurstone, Dr. Carney Landis, Dr. Clark L. Hull, Dr. Luton Ackerson and Lilian Davis for valuable suggestions in the course of this study and in the preparation of the final manuscript, and to those staff members of the Institute and others who served as subjects.

[2] A review of the literature bearing on this relation has been published under a separate title (*Psychol. Bull.*, 1929, 26, 185–201).

Blood Pressure and Electrical Changes after Stimulation

Apparatus. The physiological changes with which this study is chiefly concerned are the galvanic skin-reflex[3] and blood pressure. Incidental to an understanding of these we have also studied concomitant changes in pulse, vasocon-

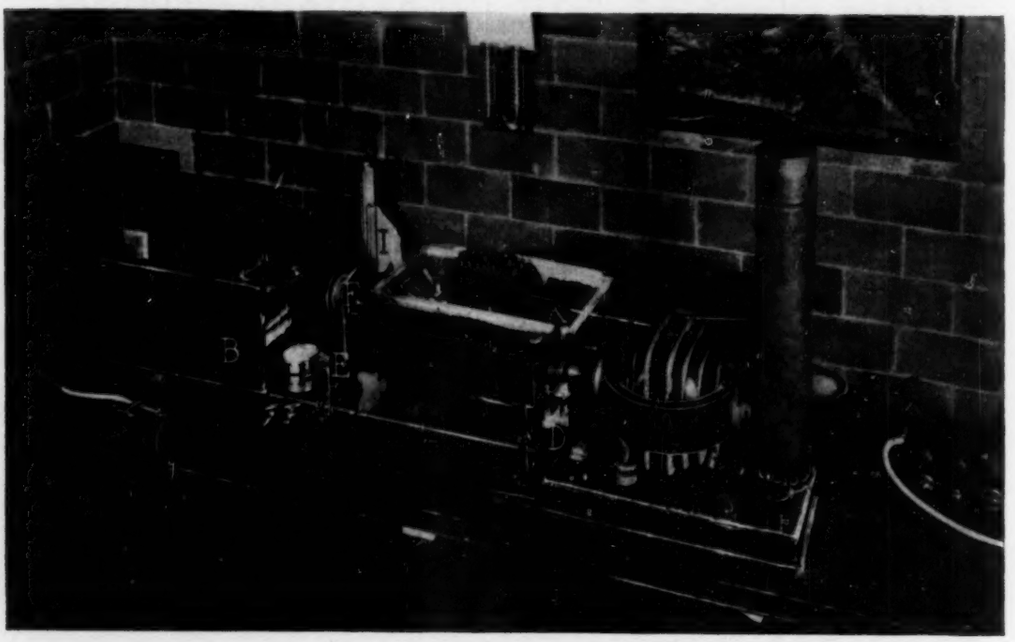


Plate I

striction, and respiration. As a means of obtaining simultaneous records of these reactions we have employed the apparatus represented in Plate I. An Erich Huth string galvanometer[4] is shown at *A*, with the accompanying photokymograph, *B*, and the lamp house, *C*. To this has been added a Jacquet time marker, *D*, which interrupts the beam of light through the apparatus at 1-sec intervals; also Marey tambours, *E*, for recording respiration and certain other physiological variables. A small desk galvanometer, *F*, with an extended pointer is used in conjunction with vacuum

[3] In this article we shall again follow the lead of Gildemeister (M. Gildemeister, *Arch. f. d. ges. Physiol.*, 1922, 197, 432–436) and employ the term galvanic skin-reflex (galvanischer Hautreflex) because it does not make the assumptions implied by the term psycho-galvanic reflex.

[4] A sheet-metal box built around the galvanometer for purposes of electrical shielding and thermostatic control has been removed for better representation.

tube amplification, for recording changes in perspiration.[5] Blood pressure records are obtained by means of a bronze bellows, *H*, of twelve laminations.[6]

The bellows, connected by a tube with a blood pressure cuff on the subject's ankle,[7] acts by a rack and pinion upon an axis to which are attached two pointers. These throw shadows, separated from one another by a fixed distance, upon the slit of the photokymograph. A change of pressure in the bellows sufficient to throw the shadow of one pointer off from the sensitive paper will bring the other pointer into the recording position. The slipping of the mesh between the rack and pinion will compensate for still further changes in pressure. The blood pressure apparatus is calibrated against a mercury column, *I*, so that by an empirically constructed scale, changes as small as 1/20 of a millimeter of mercury can be read directly from the record. At the point of minimal deflection per unit pressure a change of 1 mm Hg produces 1 cm deflection. The total compression is kept at about 90 mm Hg, a point well between the extremes of systolic and diastolic pressures for normal subjects, and satisfactory records of relatively long duration may be obtained with little discomfort due to lessened circulation of the limb. The blood pressure cuff is attached to the subject's ankle instead of the arm both because it affords much less discomfort in this position and because it is less affected by the involuntary start following stimulation.

Measurements of blood pressure change relate to the magnitude in mm Hg of the first fluctuation following the excitation. Measurements are made from the prevailing base line of the cardiac oscillations. Only the first deflection occurring within five seconds after the stimulus is considered in this part of the study because it is the only change which can be definitely related to the initial galvanic, pulse, vasoconstrictor, and immediate respiratory changes following stimulation and also because any later change is due in part, at least, to a tendency to return to equilibrium, and not directly to the original excitation.[8]

---

[5] This was not used for all subjects, in view of the high correlation between secretory and electrical changes. For details of apparatus and early results see Darrow, Sensory, secretory, and electrical changes in the skin following bodily excitation, this JOURNAL 1927, 10, 197–226. For data on moisture in relation to the present problem, see Table VI. We are indebted to Dr. Harvey Carr of the Psychological Laboratory of the University of Chicago for the loan of the moisture recorder constructed and previously used there.

[6] Credit for suggesting the use of a metal bellows instead of the rubber parts which are difficult to maintain and standardize is due to Mr. Keeler and Dr. Miles of Stanford University.

[7] In Table XI are given data secured with a blood pressure cuff on the arm. Tests of B.P. changes in the arm and leg showed little difference when the subject was in a semi-reclining position. The same applies to vasoconstriction. See Hallion & Comte, Recherches sur la circulation capillaire chez l'homme, *Arch. de physiol.*, 1894, 26, 318–411.

[8] Slight erratic deviations from the base line occurring for one or two pulse beats, possibly due to bodily movement, are ignored in determining the amount of deflection. Gross bodily movements sufficient to effect a sudden change of the general base line of the blood pressure record, to upset the respiratory record, or to be seen by the experimenter, were a basis for discarding any reaction. Blood pressure changes during the successive phases of the galvanic reflex are given in Table XIa.

The galvanic reflex is recorded by the string galvanometer. The electrodes completing this circuit are applied to the palm of the hand, a region that has been previously shown to produce a maximum of perspiration and of electrical change following stimulation, and to the dorsal surface of the upper arm, a position of little or no secretory or electrical change.

The electrodes are of sheet zinc, one a rectangle 3 by 4 inches and the other a disk 1½ inches in diameter, and both are rendered relatively non-polarizable by covering them with a paste of kaolin and zinc sulphate inside a cover of moist chamois skin. The zinc sulphate solution is used in a weak, physiologically isotonic concentration in order to reduce to a minimum artifacts of potential production and of irritation to the skin surface. The electrode of large area is attached to the upper arm and previous to application the skin underneath is pricked in four or five places with a fine needle to reduce the effects of electrical resistance, polarization and capacity. Changes in the intact skin of the palm are thus rendered relatively more effective in their influence upon the course of a record.

No exo-somatic E.M.F. is employed, save that about every 1½ sec a potential of known magnitude (20 millivolts) is automatically impressed upon the subject for ½ sec for purposes of electrical measurement (see 5 & 6, Plate II). The fact that this gives two parallel electrical records, one with and the other without an external potential makes this procedure a combination of the methods of Féré and Tarchanoff. The exo-somatic potential (20 millivolts) is, however, relatively small compared with the one-to-five volts often employed when following the method of Féré. The sensitivity of the string is determined frequently in the course of a record by substituting in the place of the subject a known resistance of 20,000 ohms including the resistance of the string (see Plate II). The data used when we desire to calculate the resistance and potential changes during the subject's reaction are (1) the deflection from zero potential produced by the subject, (2) the deflection by a known potential acting through the subject, (3) the deflection by a known potential acting through a known resistance, and (4) the known resistance of the galvanometer string and the circuit.[9] Inasmuch as all these data were not available in the case of all of the reactions of many of the subjects, while the amplitude of any change in the main portion of the record (that with no external E.M.F.) could in most instances easily be read in millimeters, the latter measure has been used in the first general presentation of results.[10]

The analysis of the deflections into potential and apparent resistance changes is given in the case of those reactions and those subjects where all of the significant data were unambiguously present, and the sensitivity of the galvanometer relative to the condition of the subject was such as to give 20-millivolt deflections of an amplitude to be measured with relative accuracy. All reactions involving very small

[9] For a complete description of the method see Darrow, *op. cit.*, pp. 202–203.

[10] This measure is corrected in each case for effects of temperature change upon the sensitivity of the galvanometer.

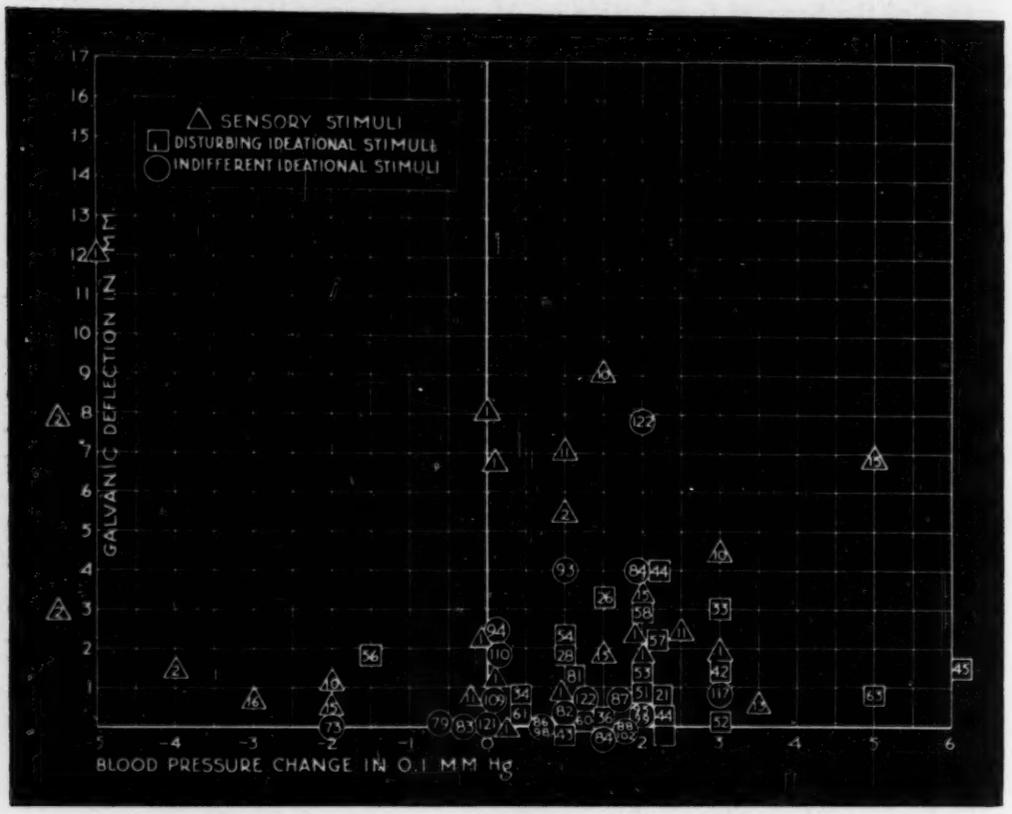
deflections were, therefore, discarded by the latter method of treatment. The galvanic reactions following stimulation are measured at the point of maximal deflection, which corresponds in most instances to the point of greatest decrease in apparent resistance.

Records of respiration are obtained by means of thoracic and abdominal pneumographs of the Sommer type, acting on Marey tambours. Inasmuch as respiration produces effects which are of special importance because of their influence upon the circulation, a classification of these changes as factors in blood pressure is presented in Table V.

Procedure. The subject lies in a reclining chair with his back toward the apparatus, and in this position the experimenter may note any appreciable movement without himself being seen. The thoracic and abdominal pneumographs, the electrodes, and the ankle blood pressure cuff are attached to the subject and he is requested to be as comfortable as he can, to relax and to move as little as possible. He is then informed that there will be in irregular order four types of stimuli; (1) sensory stimuli, such as a slap or a sudden noise, (2) verbal sounds, such as 'dog' or 'tree,' (3) questions, such as 'Have you had your breakfast?' and (4) pictures, words, or questions presented on an exposure apparatus. During the preliminary and final portions of the experimental period the subject is requested to respond orally to the ideational stimuli. During the remainder of the time he is instructed "only to think the response."

Stimuli. In the early part of the study a wide variety of stimuli were thus presented to the subjects in controlled mixed order and the results were combined in a variety of ways in search for significant differences and uniformities of reaction. As a result of this exploration the classification of (1) slaps, sudden noises, etc., as *sensory stimuli*, (2) of such words as 'dog,' 'pencil' or such questions as 'Have you had lunch?' as *indifferent ideational stimuli*, and (3) of such words as 'love,' 'kiss,' or 'masturbation,' or such questions as 'Have you an inferiority complex?' as *emotional* or *disturbing ideational stimuli* was adopted. These terms are used only for lack of better ones by which to designate respectively;

(1) momentary excitation of sensory end-organs causing immediate physiological effects, but calling for no extensive association of ideas,[11] (2) momentary excitation in which the stimulation of sensory end-organs is but incidental to the initiation of associative processes, and (2*a*) momentary excitation in which the activity of ensuing associative processes is



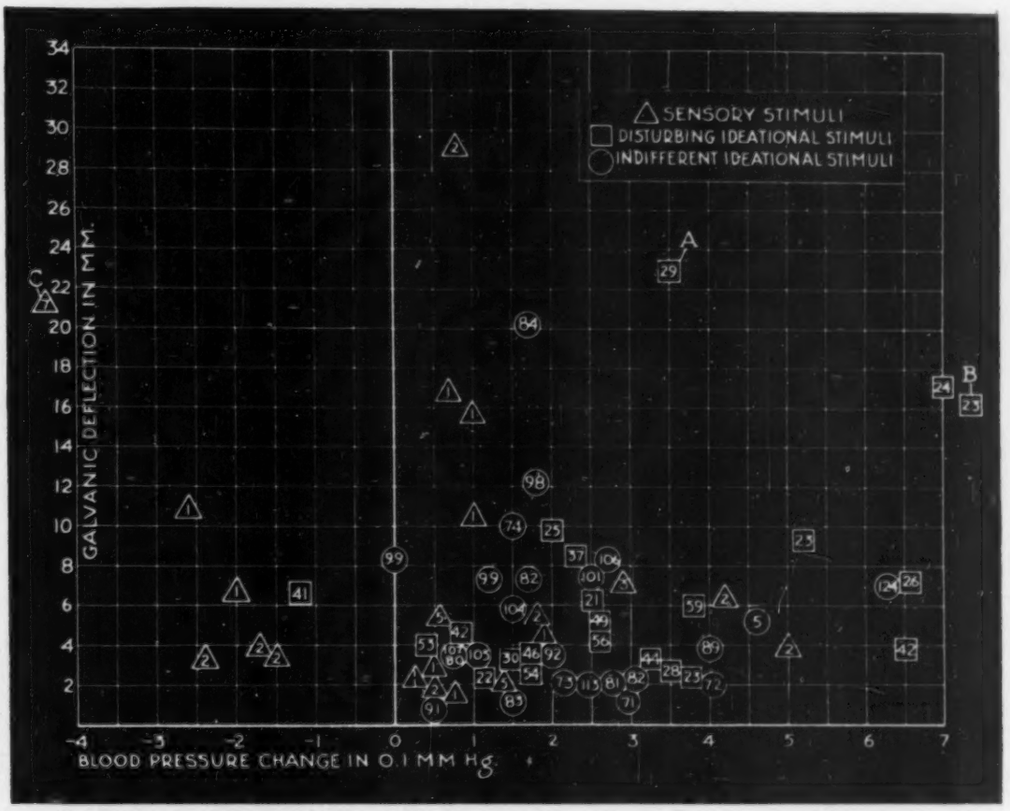
GRAPH 1: SUBJ. 1.

the occasion of marked organic changes. A partial list of these stimuli is presented in connection with Graphs 1 to 5.

The placing of any of these stimuli in one of the three classes was determined first on the basis of the ratings of persons who grouped them independently of any

[11] Satisfactory stimuli for this sort of study must be of such a character that they will become physiologically effective immediately upon presentation; otherwise it will be uncertain what results should be attributed to the stimulus. In the case of taste and odor stimuli the moment of effectiveness depends upon movements of the subject. These therefore proved to be unsatisfactory and their exclusion should be kept in mind as a limitation of the use here made of the term 'sensory.' All stimuli whether termed sensory or ideational occurred unexpectedly in the sense that the subject did not know when they would be given. All were preceded by expectation that at some moment they would occur.

knowledge of the physiological reactions elicited, and secondly, on the basis of the retrospective reports of the subjects. It is quite probable that stimuli selected for the specific purpose of representing each of the three classes would have shown differences more clear-cut than is possible in the classification of a more or less graded series of excitations. In any case we may expect that in the actual experimental situation there will be many occasions when the sensory stimulus will arouse a train of associ-



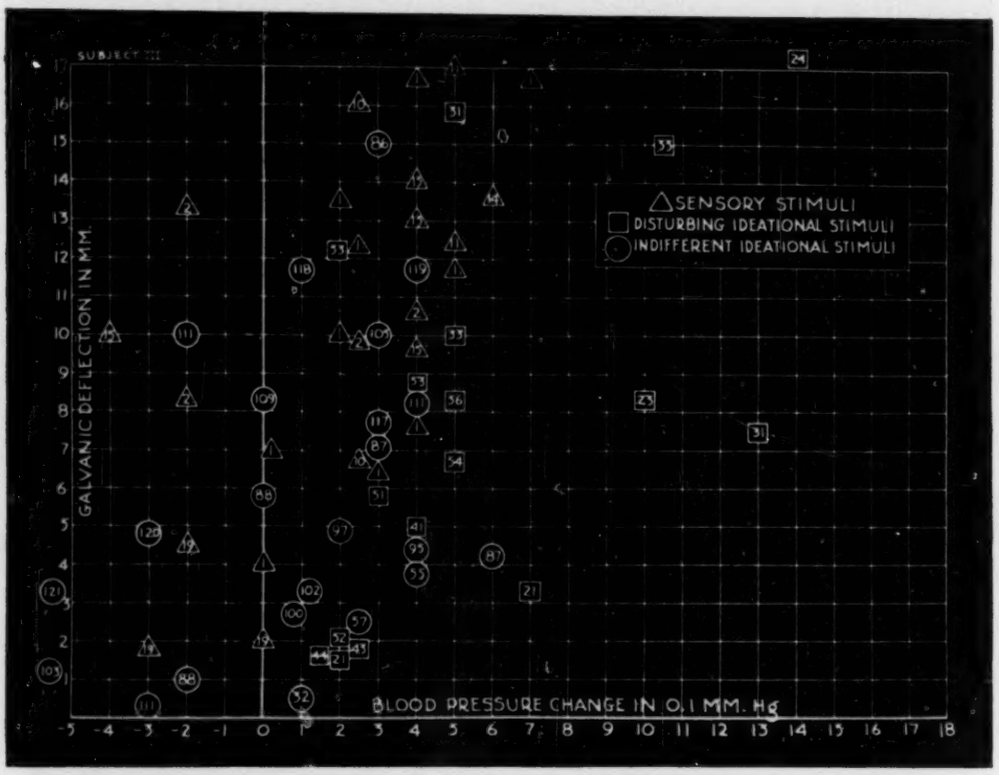
CRAPH 2: SUBJ. 2.

ations; while there will be other times when a stimulus which is usually 'ideational,' may act in no way significantly different from a purely sensory situation. On the other hand, a presumably indifferent word like 'pencil' may have profound symbolic or other significance, and words usually considered to be provocative of emotion, like 'kiss' or 'marriage,' may, for some subjects or on some occasions, lack any disturbing quality. Only the average of reactions to a group of sensory, indifferent ideational, or disturbing ideational stimuli may be assumed to represent the typical response to any particular class.[12]

[12] It is interesting to note that in the retrospections which followed each series of stimuli very few words were reported as having caused any 'feeling,' even when marked physiological reactions were recorded. That these subjects were inured to the consideration of case history material is, perhaps, a reason why little or no affect would be expected. It is also a reason along with the frank manner in which the reports were usually given for assuming that in most instances the subjects were trying to report

Results

Excerpts from two typical records are shown in Plate II. These sections of the records are chosen because the stimuli occurred here in rapid succession and they illustrate, in a space sufficiently short for reproduction, the differences in the reactions to the several classes of stimuli. *C* and *G* are

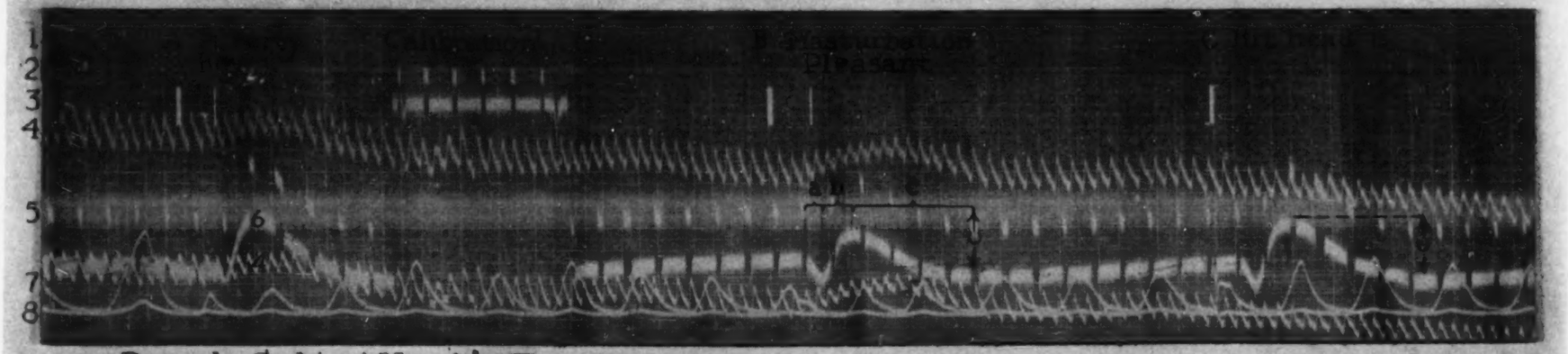


Graph 3: Subj. 3.

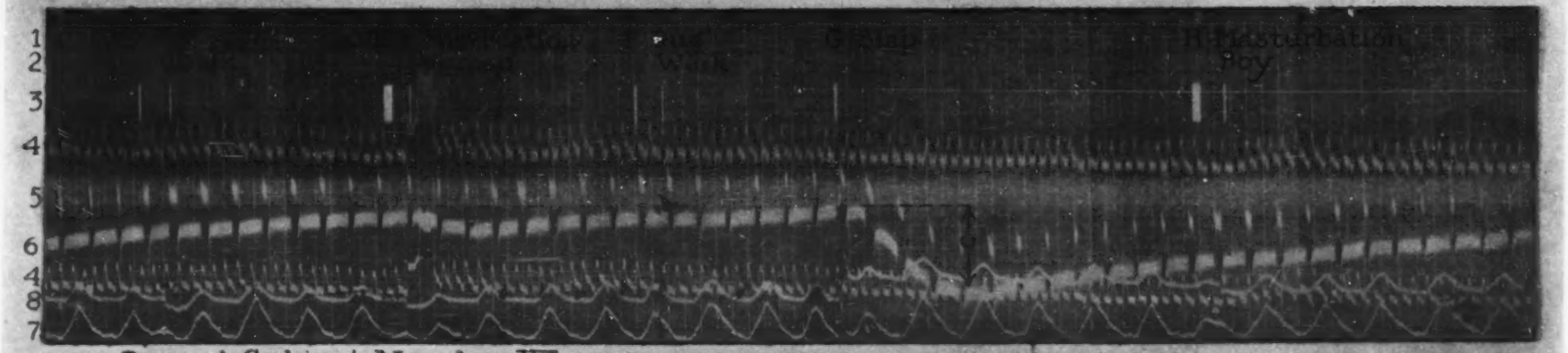
instances of reactions to sensory stimuli, and it will be noted that in both instances there is a very decided electrical disturbance and that there is no rise—even a slight drop—in blood pressure. Both are accompanied by a respiratory gasp or 'catching of the breath,' followed by deeper breathing in *C*, and by breathing with abdomen expanded in *G*. *A*, *B*, *E*, and *H* illustrate the reactions typical of the disturbing ideational

the truth. That there is physiological evidence of disturbances which are below the limen of recognition as emotion is a fact to be borne in mind in any consideration of the nature of 'emotional' reaction. See H. C. Syz, Observations on the unreliability of subjective reports of emotional reactions, *Brit. J. Psychol.* (*Gen. Sect.*), 1926, 17, 119–126.

PLATE II.



Record, Subject Number II

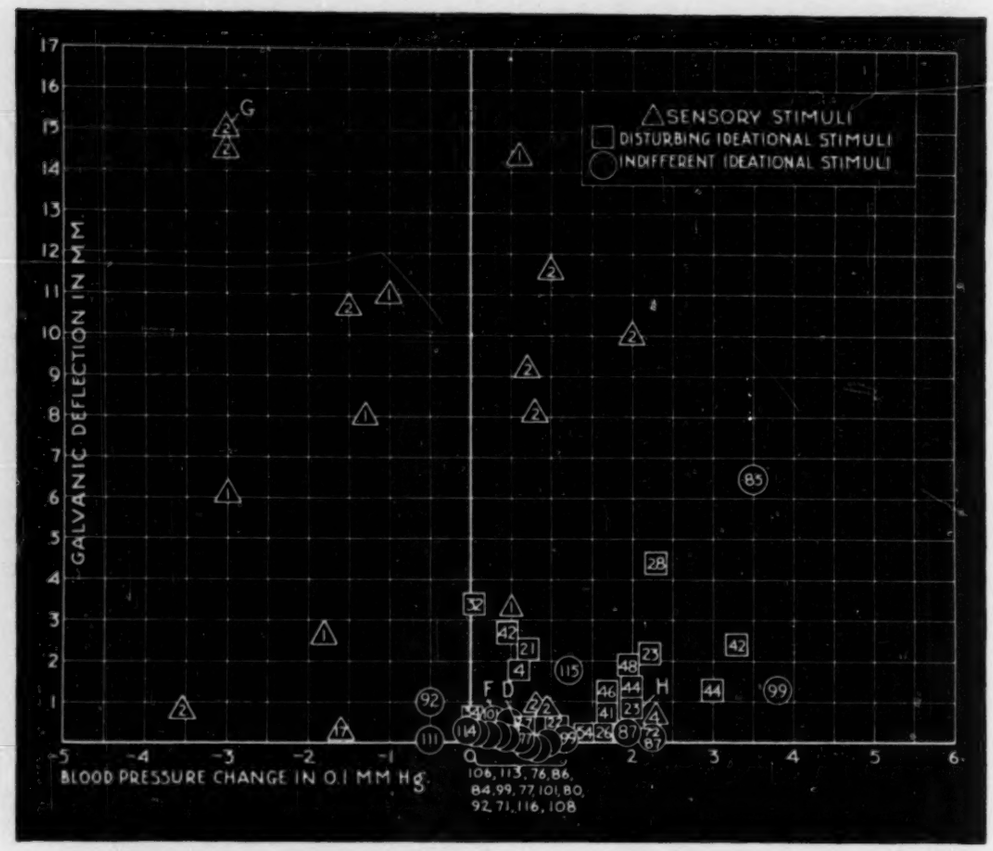


Record, Subject Number IV

1. Stimuli
2. Responses
3. Signal marks
4. Blood pressure record
5. Deflection by 20 m.v. through subject
6. Galvanic record, no external E. M. F.
7. Thoracic respiration
8. Abdominal respiration

Vertical white lines = seconds

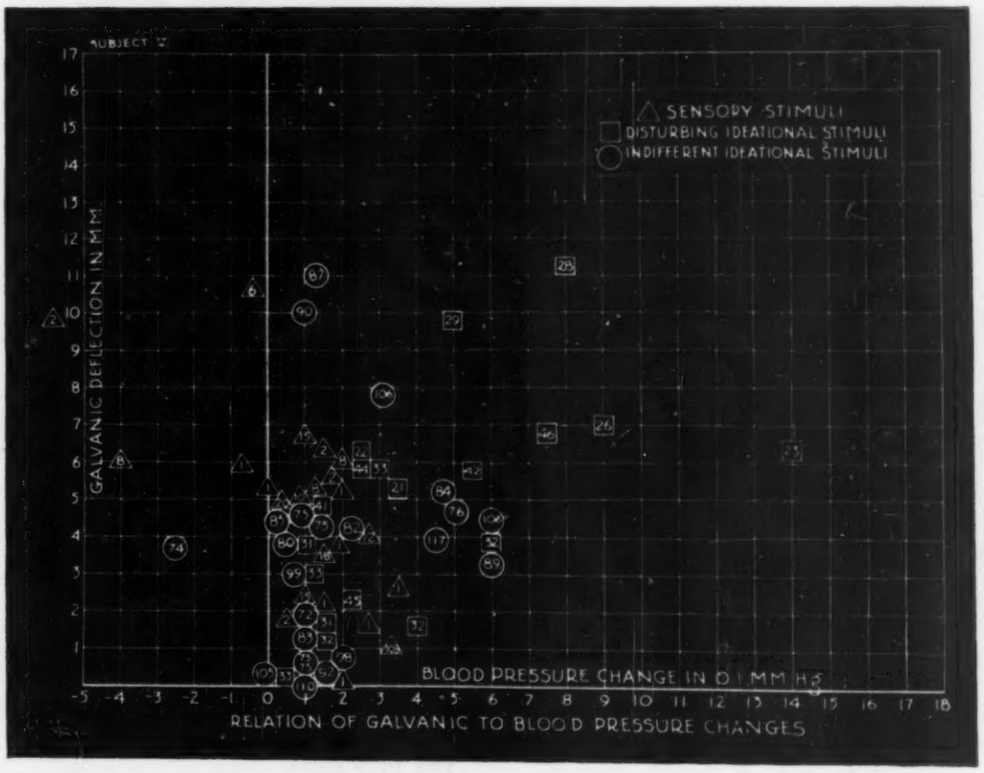
stimuli. In each instance there is relatively less galvanic disturbance than in the case of the sensory stimuli, although there is a marked rise in blood pressure. Respiration becomes momentarily more shallow. *D* and *F* are examples of the slight blood pressure rise, the small respiratory disturbance and the negligible electrical change occasioned by indifferent ideational stimuli.


SENSORY STIMULI
DISTURBING IDEATIONAL STIMULI
INDIFFERENT IDEATIONAL STIMULI
GALVANIC DEFLECTION IN MM.
BLOOD PRESSURE CHANGE IN 0.1 MM Hg.
106, 113, 76, 86, 84, 99, 77, 101, 80, 92, 71, 116, 108

GRAPH 4: SUBJ. 4.

In order to represent changes in the galvanic reflex and in blood pressure in what may be considered as two physiological dimensions, the device of portraying the magnitude of the electrical changes by distance on the ordinate, and blood pressure reactions by distance along the abscissa of a two-dimensional graph, has been adopted. In Graphs 1 to 5 the data of the five subjects from whom were obtained the largest number of reactions of each class have been plotted

after this fashion.[13] The reactions *A* to *C*, Plate II, are indicated by the same letters in Graph 2; reactions *D* to *H* similarly may be found in Graph 4.


SUBJECT V
SENSORY STIMULI
DISTURBING IDEATIONAL STIMULI
INDIFFERENT IDEATIONAL STIMULI
GALVANIC DEFLECTION IN MM.
BLOOD PRESSURE CHANGE IN 0.1 MM. HG.
RELATION OF GALVANIC TO BLOOD PRESSURE CHANGES

GRAPH 5: SUBJ. 5.

STIMULI

(Numbers correspond to those in Graphs 1 to 5)

I SENSORY STIMULI

1 Shout
2 Slap face
3 Box falls (noise)
4 Buzzer; conditioned to words when in circle or square
5 Clap hands; conditioned to words when in circle or square
6 Gun fire
7 Hit head
8 Hit with rubber tube
9 Hit with match box
10 Jarring noise (weight on platform)
11 Pull hair
12 Slam boards
13 Snap fingers
14 Scrape saw
15 Touch head
16 Tap table
17 Bell (sound)
18 Chair drops
19 Click
20 Colored paper

[13] Galvanic changes have, of course, been corrected to allow for changes in the sensitivity of the galvanometer.

II Disturbing Ideational Stimuli

21 Constipation
22 Guts
23 Masturbation
24 Menstruation
25 Nasty
26 Petting
27 Physic
28 Pregnancy
29 Puberty
30 Sex
31 Man-underwear (picture)
32 Woman-underwear (picture)
33 Nude woman (picture)
34 Toilet
35 Purity
36 Embarrassment
37 Rotten

41 Divorce
42 Kiss
43 Like babies?
44 Love
45 Man
46 Marriage
47 Woman
48 Sweetheart
49 Dance
51 Afraid I'll find out something?
52 Compensating for inferiority?
53 Contemplate suicide—ever?
54 An inferiority complex?
55 Like popularity?
56 Wish you were a success?
57 Wish you were a man?
58 Know you're pretty?
59 Proud?
60 Need money?
61 Fear?

III Indifferent Ideational Stimuli

(Presumably occasioning in the majority of subjects only indifferent ideational reactions)

71 Apple
72 Basket
73 Bath
74 Bird
75 Black
76 Boot
77 Box
78 Bread
79 Dinner
80 Cat
81 Carpet
82 Chair
83 Coat
84 Dog
85 Door
86 Floor
87 Glass
88 Go to Church?
89 Grass
90 Hand
91 Head
92 Ice
93 Like cheese?
94 Like spring?
95 Like your work?
96 Milk
97 Money
98 Pen
99 Pencil
100 Play golf?
101 Rug
102 Sufficient sleep?
103 Speak Spanish?
104 Step
105 Table
106 Tree
107 Window
108 Color (picture)
109 Man's head (picture)
110 Woman's head (picture)
111 Woman (picture)
112 Cap
113 Stone
114 Sun
115 Pond
116 Wall
117 Swim
118 Money (picture)
120 Paper
121 Dancers (picture)
122 Slap (word)
123 Religion
124 Tin

Sensory stimuli are represented in each graph by triangles, disturbing ideational stimuli by squares, and indifferent ideational stimuli by circles. The specific stimulus concerned in any particular reaction may be determined by noting its number in the square, circle, or triangle on the graphs and then referring to the corresponding number in the accompanying list of stimuli.

These graphs indicate that sensory stimuli often produce marked galvanic changes with relatively little or even a minus change in blood pressure. This is evident from the prevalence of triangles toward the upper left portion of the chart. Disturbing ideational stimuli, on the other hand, are often characterized by a relatively large rise in blood pressure, as is evident from the preponderance of the squares upon the right-hand portion of the graphs. The indifferent ideational stimuli are characterized by less of either galvanic or circulatory change, as is evident from the grouping of circles toward the left and lower areas. To show that these are more than chance differences the averages of the reactions of these five subjects and the differences in their reactions to the three stimulating conditions are given in Table I. In each

TABLE I

THE EFFECTS OF TYPE OF STIMULATION UPON GALVANIC AND CIRCULATORY CHANGES

(Shows a high probability that the amplitude of the blood pressure changes will differentiate a group of *disturbing ideational* from *sensory* or *indifferent ideational* stimuli.)

Subj.	Total N	(1) Sensory Stimuli			(2) Disturbing Ideational Stimuli			(3) Indifferent Ideational Stimuli			Column (2) Minus (1)		Column (2) Minus (3)	
		N	Galv.	B.P.	N	Galv.	B.P.	N	Galv.	B.P.	Galv.	B.P.	Galv.	B.P.
1	77	27	3.7 ±0.4	−0.03 ±0.4	23	1.3 ±0.2	2.0 ±0.3	27	1.1 ±0.2	0.6 ±0.2	*−2.4* ±0.5	*2.0* ±0.5	0.2 ±0.3	*1.4* ±0.3
2	68	22	7.8 ±1.0	0.1 ±0.4	21	6.9 ±0.9	3.3 ±0.3	25	5.3 ±0.6	2.4 ±0.2	−0.9 ±1.3	*3.2* ±0.5	1.6 ±1.0	0.9 ±0.4
3	66	28	10.6 ±0.6	2.5 ±0.4	16	7.9 ±1.0	7.4 ±0.9	22	7.0 ±0.6	1.1 ±0.5	−2.7 ±1.2	*4.9* ±1.0	0.9 ±1.2	*6.3* ±1.0
4	65	24	4.9 ±0.3	0.7 ±0.4	15	5.6 ±0.5	4.8 ±0.6	26	3.5 ±0.4	2.0 ±0.3	0.7 ±0.6	*4.1* ±0.7	*2.1* ±0.6	*2.8* ±0.7
5	64	22	5.5 ±0.7	−0.3 ±0.5	17	1.2 ±0.2	1.6 ±0.1	25	0.7 ±0.2	0.9 ±0.1	*−4.3* ±0.8	*1.9* ±0.5	0.5 ±0.3	*0.7* ±0.2

Differences over three times the P.E. of the difference are italicized.

case the averages of blood pressure change following disturbing ideational stimuli are larger than those following sensory stimuli by more than three times the probable error of the difference. On the other hand, the galvanic changes following the disturbing ideational stimuli are generally smaller than those following sensory stimuli. A comparison of the effects of disturbing and indifferent ideational stimuli indicates that the former tends to occasion physiological responses of greater magnitude than the latter, no matter whether the criterion of disturbance is the galvanic or the circulatory change, but that the difference is likely to be greater, as compared with the probable error of the difference, in the case of blood pressure.

The difficulty in getting volunteers to return repeatedly for a not altogether pleasant experimental procedure, the limited number of subjects available, the considerable degree of adaptation to the stimuli which occurred after a few sittings, and the imperfections in the mode of registration and control are all reasons why numbers of valid reactions sufficient for statistical analysis have not been secured on all subjects.[14] In Table II are given data on twenty-three subjects. It is apparent from the columns of differences that except in two cases the 'disturbing ideational' stimuli produced smaller galvanic deflections but larger average blood pressure rise than the 'sensory' stimuli; and that, as might have been expected, they occasioned larger changes both in blood pressure and in galvanic response than the indifferent ideational condition.

Although these individuals differed considerably in the absolute magnitude of their galvanic or circulatory changes, as is apparent from a comparison of the measures within any column in Table II, yet for each subject the relative magnitude of the responses to the three conditions was rather constant. This is shown in Table III where each subject's average reaction to all classes of stimuli is taken as a standard with which to compare, in terms of percentage, his reactions to each of the three classes. The consistency with which

[14] Additional cases are to be found in Table XI*a*.

TABLE II

AVERAGES OF GALVANIC AND BLOOD PRESSURE CHANGES FOLLOWING VARIOUS TYPES OF STIMULATION

(Shows the consistency with which subjects manifested a lower average galvanic and a higher average blood pressure change for disturbing ideational than for sensory stimuli.)

Subj.	Total N	(1) Sensory Stimuli N	Galv.	B.P.	(2) Disturbing Ideational Stimuli N	Galv.	B.P.	(3) Indifferent Ideational Stimuli N	Galv.	B.P.	Column (2) Minus (1) Galv.	B.P.	Column (2) Minus (3) Galv.	B.P.
1	77	27	3.7	−0.03	23	1.3	2.0	27	1.1	0.6	− 2.4	2.0	0.2	1.4
2	68	22	7.8	0.1	21	6.9	3.3	25	5.3	2.4	− 0.9	3.2	1.6	0.9
3	66	28	10.6	2.5	16	7.9	7.4	22	7.0	1.1	− 2.7	4.9	0.9	6.3
4	65	24	4.9	0.7	15	5.6	4.8	26	3.5	2.0	0.7	4.1	2.1	2.8
5	64	22	5.5	−0.3	17	1.2	1.6	25	0.7	0.9	− 4.3	1.9	0.5	0.7
6	38	17	10.8	0.7	14	8.9	1.5	7	7.5	1.0	− 1.9	0.8	1.4	0.5
7	37	13	3.0	−0.3	10	1.7	1.4	14	0.7	0.02	− 1.3	1.7	1.0	1.4
8	36	18	8.9	0.6	13	3.4	1.7	5	2.4	1.3	− 5.5	1.1	1.0	0.4
9	34	17	13.4	1.2	10	13.7	2.6	7	7.5	0.9	0.3	1.4	6.2	1.7
10	33	10	3.2	1.1	15	1.9	3.3	8	1.6	2.5	− 1.3	2.2	0.3	0.8
11	31	14	3.5	−0.2	8	1.7	1.5	9	1.3	0.9	− 1.8	1.7	0.4	0.6
12	30	11	6.2	1.8	9	5.7	2.0	10	5.2	1.6	− 0.5	0.2	0.5	0.4
13	26	6	35.5	1.0	5	13.2	0.7	15	13.4	1.3	−22.3	−0.3	−0.2	−0.6
14	25	8	11.4	−0.4	10	5.6	0.6	7	3.0	0.3	− 5.8	1.0	2.6	0.3
15	24	5	2.5	2.5	12	2.1	3.9	7	1.7	3.2	− 0.4	1.4	0.4	0.7
16	22	10	8.9	1.5	6	5.6	2.9	6	3.9	1.3	− 3.3	1.4	1.7	1.9
17	22	9	25.5	0.9	8	9.2	1.8	5	4.5	0.9	−16.3	0.9	4.7	0.9
18	21	9	18.7	3.0	7	12.5	5.9	5	6.5	2.9	− 6.2	2.9	6.0	3.0
19	21	10	5.2	0.6	6	4.1	2.1	5	3.1	1.5	− 1.1	1.5	1.0	0.6
20	21	10	6.1	0.8	5	3.5	1.2	6	3.0	1.0	− 2.6	0.4	0.5	0.2
21	18	7	2.9	0.6	5	2.1	1.3	6	1.6	0.7	− 0.8	0.7	0.5	0.6
22	14	4	5.7	2.5	7	1.5	6.9	3	2.9	6.3	− 4.2	4.4	−1.4	0.6
23	13	2	3.1	0.9	6	2.8	3.9	4	2.3	2.5	− 0.3	3.0	0.5	1.4
Mean			*	.95		*	2.80		*	1.61	*	1.85	*	1.18
P.E.				±0.13			±0.25			±0.18	†	±0.18*	†	±0.19*

P.E. dif. ($\sqrt{PE_{m1}^2 - PE_{m2}^2 - 2PE_{m1}PE_{m2}r^{1,2}}$)

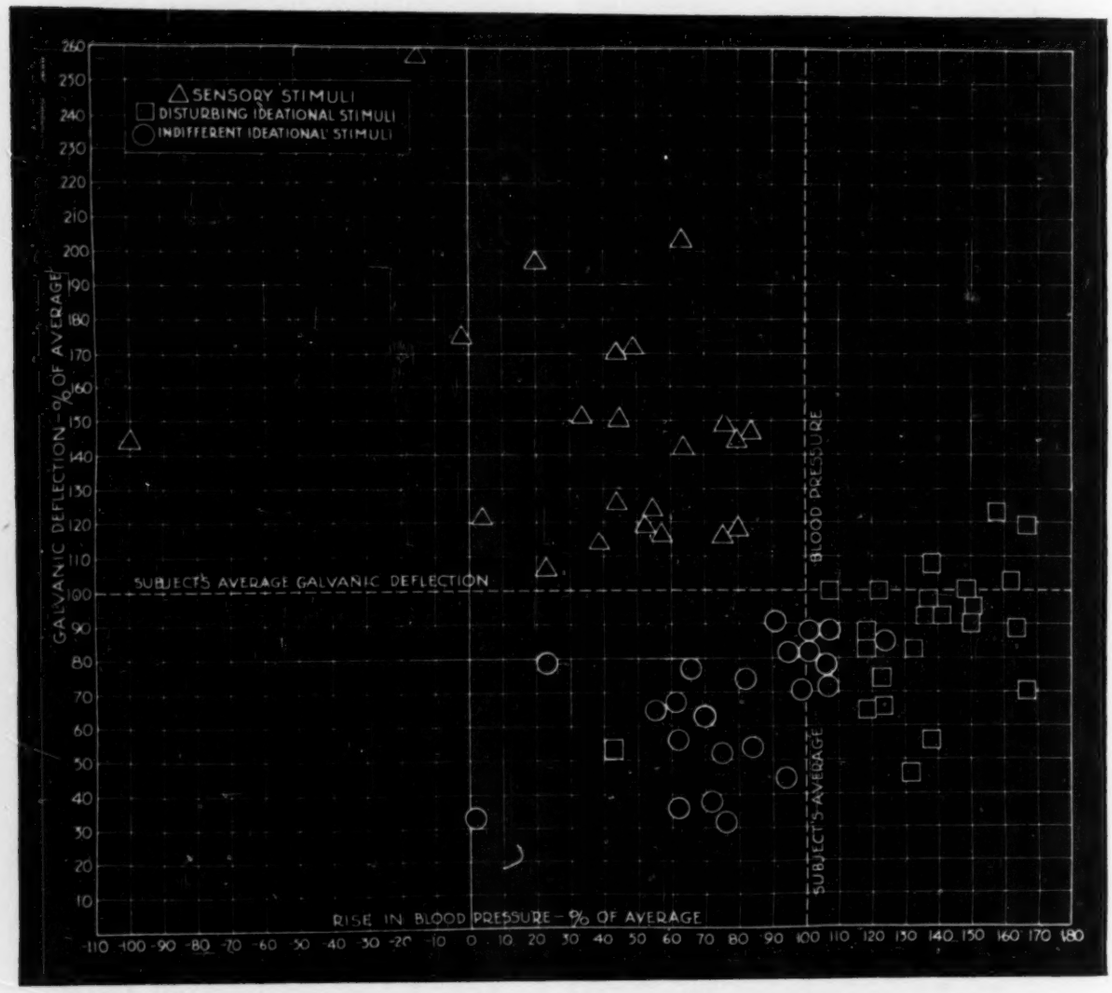
* Averages are not given because differences in the sensitivity of the galvanometer and differences in the skin resistances of the various subjects render measures of the amplitude of the galvanic deflections in mm not comparable from individual to individual.

The five cases were presented in Table I. Additional cases analyzed with regard to the temporal relation of blood pressure change to the galvanic reflex are to be found in Table XI.

sensory stimuli occasioned more than 100 percent of the average galvanic reaction, and disturbing ideational stimuli more than 100 percent of the average blood pressure change, is apparent. Furthermore, the uniformity with which blood pressure showed the greater percentage difference between disturbing and indifferent ideational stimuli is of practical

significance because of what it may indicate as to the value of this measure in tests for the presence of emotional ideas.

The percentages given in Table III have been plotted in Graph 6. The various galvanic deflections in terms of percent of the average are here measured by distance on the ordinate, and blood pressure changes, also in percent of the



GRAPH 6: AVERAGE REACTIONS OF 23 SUBJECTS.

subject's average level of response, by distance on the abscissa. Sensory stimuli are again represented by triangles, disturbing ideational stimuli by squares, and indifferent ideational stimuli by circles. The average response of each subject in each of the two physiological measures is coincident with the dotted lines drawn at the respective 100 percent marks on the graph.

TABLE III

TABLE III

PERCENTAGE RELATION OF EACH CLASS OF REACTIONS TO SUBJECT'S AVERAGE LEVEL OF REACTION

(Shows the consistency with which subjects gave a galvanic response above 100 percent of the average for sensory stimuli and a blood pressure rise above 100 percent of the average for disturbing ideational stimuli)

	Ave. Galvanic Response						Ave.* Blood Pressure Change					
		(1)	(2)	(3)	Difference			(1)	(2)	(3)	Difference	
Subj.	Ave. React'n (mm)	Sen-sory Stim. %	Dist'b'g Idea'l Stim. %	Indiff't Idea'l Stim. %	Col. (2) Minus (1)	Col. (2) Minus (3)	Ave. Level Re-act'n (mm Hg)	Sen-sory Stim. %	Dist'b'g Idea'l Stim. %	Indiff't Idea'l Stim. %	Col. (2) Minus (1)	Col. (2) Minus (3)
1	2.03	175	65	56	−110	9	1.64	− 2	119	62	121	57
2	6.40	121	108	83	− 13	25	2.36	4	138	101	134	37
3	8.89	119	89	79	− 20	10	4.53	55	164	23	109	141
4	4.57	107	123	77	16	46	3.05	23	158	66	135	92
5	2.15	258	56	32	−202	24	1.15	− 25	138	76	163	62
6	9.08	119	98	82	− 2.1	16	1.06	55	138	97	83	−41
7	2.01	151	83	33	− 68	50	1.03	− 34	133	2	167	131
8	5.24	170	66	45	−104	21	1.42	46	123	94	77	29
9	11.54	116	119	65	3	54	1.57	77	167	57	90	110
10	2.07	150	94	78	− 56	16	2.39	45	138	106	93	32
11	1.80	197	93	74	−104	19	1.10	20	140	82	120	58
12	5.70	108	100	91	− 8	9	1.82	102	108	91	6	17
13	24.89	143	53	54	− 90	− 1	1.59	64	43	84	−19	41
14	7.81	145	71	38	− 74	33	.36	−100	167	72	267	95
15	2.10	117	100	82	− 17	18	3.21	79	122	100	43	22
16	6.15	145	92	63	− 53	29	1.92	80	150	70	70	80
17	12.54	204	74	36	−130	38	1.46	63	123	62	60	61
18	12.57	149	99	52	− 50	47	3.94	76	149	75	73	74
19	4.14	126	98	75	− 28	23	1.42	44	150	107	106	43
20	4.20	146	83	71	− 63	12	1.04	81	119	99	38	20
21	2.35	123	88	67	− 35	21	1.12	55	119	60	64	59
22	3.38	171	46	85	−125	−39	5.22	47	132	121	85	11
23	2.72	114	103	83	− 11	20	2.44	39	162	102	123	60
Mean		146.70	87.00	65.26	−59.26	21.74		38.87	134.78	78.65	*96.00*	*56.13*
P.E.		±5.07	±2.80	±2.51	± 7.22	±2.69		±6.31	±3.65	±3.75	*±8.08*	*±5.64*

* Only reactions involving a rise in blood pressure are considered in determining the general level of reaction. Both rises and drops in blood pressure are used in determining the average response to each class of stimuli. This is to avoid the possibility of plus and minus changes cancelling and thus giving zero levels of reaction, and percentages of this level which would approach infinity.

Percentages are calculated from data of two decimal places.

TABLE IV

RESISTANCE AND POTENTIAL CHANGES UNDER VARIOUS STIMULATING CONDITIONS

(Shows a larger decrease in resistance for sensory stimuli than for disturbing ideational stimuli except in cases which are starred. It shows a smaller rise in blood pressure for sensory stimuli except in cases checked. It shows no consistent difference in potential under these two conditions.) The potential is of palm relative to arm.

Subj.	Before Stim. (Ave.)		Sensory Stimuli				Disturbing Ideational Stimuli				Indifferent Ideational Stimuli			
	Res.	Pot.	N	Res. Change	Pot. Change	B.P. Change	N	Res. Change	Pot. Change	B.P. Change	N	Res. Change	Pot. Change	B.P. Change
	ω	mv		ω	mv	mm Hg		ω	mv	mm Hg		ω	mv	mm Hg
2	12,104	−61.87	9	− 789*	+11.74	−2.47	6	− 922*	+13.94	+4.25	11	− 1,056	+ 8.80	+ .66
3	29,472	+11.08	19	− 5,996	−18.56	+2.69	11	− 5,510	−13.36	+3.09	11	− 5,355	−11.88	+1.15
4	19,451	−56.13	4	− 3,449	− 4.60	−2.88	4	− 1,815	− 9.00	+1.30	3	− 1,695	− 3.20	−1.50
5	32,336	+ 4.29	8	− 4,229	− 4.38	− .75	3	− 4,220	− 4.34	+1.97	3	− 3,754	− 2.22	+2.30
8	53,734	+14.33	8	− 4,709	− 4.20	+1.50	3	− 4,040	− 5.80	+2.70	1	− 3,797	− 4.20	− .30
9	70,180	+29.30	10	− 4,306	− 5.30	+1.14	5	− 3,626	− 9.00	+4.60	7	− 5,029	− 9.20	+1.20
11	69,322	+ 8.60	12	− 8,108	+ 2.60	− .74	7	− 3,695	− .80	+2.01	4	− 2,517	− .80	+ .70
12	44,416	+ .76	7	− 9,267	− 5.00	+2.76√	5	− 7,248	− 5.20	+2.70√	6	− 6,633	− 6.90	+2.15
14	37,606	−21.97	14	− 8,527	− 2.54	− .35	14	− 6,225	− 6.01	+0.21	7	− 4,422	− 7.54	+ .39
17	74,726	−20.30	8	−36,681	−11.32	+ .71	7	−14,465	− 8.94	+1.97	No measurable reactions			
19	102,056	+27.00	5	−22,981	− 7.00	− .42	4	−22,171	− 9.80	+2.40	2	−11,087	− 6.00	+2.45
20	51,510	+18.47	9	− 5,436	− 7.00	+1.05√	5	− 3,362	− 4.80	− .10√	7	− 3,369	− 5.20	+1.40

Only reactions having large galvanic changes are measured

A further analysis of galvanic deflections into apparent resistance and potential changes shows, in the case of the larger and more easily measured reactions upon which complete data are available, that only with respect to apparent resistance is the electrical response consistently greater after sensory than after disturbing ideational stimuli. No consistent relation is evident in the case of potential changes. See Table IV.

Other Physiological Changes

The results presented thus far indicate in terms of two physiological measures, blood pressure and the galvanic reflex, a difference in the patterns of the involuntary bodily responses to three general classes of excitation. Similar differences in the reactions of other related mechanisms are also of importance. It is quite probable, on the one hand, that respiration and pulse changes are contributory to differences in blood pressure, while perspiration and vasomotor changes on the other are concomitants, if not actual causes, of differences in the galvanic reactions to various stimuli. Evidence relative to some of these other changes will be briefly presented.

Respiratory changes and blood pressure after various stimuli. A change in respiration is one of the more obvious effects of excitation. Any alteration of its force, frequency, or depth is likely to affect the pressure on the blood in the lungs or in the abdomen, and this in turn to affect peripheral blood pressure. The influence of a given type of respiration is not, however, so easy to predict as would be the case were we dealing with the result of a single unidirectional influence. A sudden expansion of the thoracic cavity on the one hand creates a negative pressure within the lungs and drains the blood from the periphery. On the other hand, the simultaneous downward movement of the diaphragm against the lower viscera tends to force the blood outward toward other parts of the body. A suggestion as to the resultant of these two effects on the blood pressure in the extremities may best be obtained by determining the frequencies with which a given type of respiratory change is associated (1) with a rise, (2) with a drop, and (3) with no change in blood pressure.

In Table V the observed respiratory changes have been classified as to form and ranked according to the differences in the frequencies with which they are associated with a rise and with a drop in blood pressure. It is apparent from the upper portion of the table that a change from deep to shallow breathing (*a*), a slowing of expiratory rate, possibly with

TABLE V

TYPES OF RESPIRATORY RESPONSES IN RELATION TO BLOOD PRESSURE CHANGE AND TYPE OF STIMULATION

	N	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*
	Frequency (percent) with which a given blood pressure change is accompanied by a given type of respiration												
Rise in B.P.....	168	12.5	12.5	7.1	6.0	14.3	1.8	1.2	0.0	0.6	6.0	7.7	30.3
Drop in B.P....	26	3.8	3.8	3.8	3.8	11.5	0.0	0.0	0.0	0.0	11.5	27.1	34.7
No change.....	37	11.8	6.8	3.4	6.8	3.4	1.7	1.7	0.0	0.0	5.1	3.4	55.9
	Frequency (percent) with which a given type of stimulus is followed by a given type of respiration												
Sensory stim....	100	3.0	12.0	8.0	8.0	21.0	0.0	1.0	0.0	1.0	9.0	20.0	17.0
Disturbing Id'l.	69	18.8	13.1	8.7	2.9	7.3	2.9	0.0	0.0	0.0	4.3	0.0	42.0
Indifferent Id'l.	62	11.3	6.5	3.2	6.5	3.2	1.6	1.6	0.0	0.0	4.8	1.6	59.7

* Generally apparent by other recorded changes and, therefore, not counted.

glottis partially closed (*b*), or a sudden expiration as in speaking (*c*), are much more frequently associated with a rise than with a fall in blood pressure. These are changes which, when strongly and artificially produced, have been found to be most frequently attended by a rise in peripheral blood pressure. On the other hand, a change from shallow to deeper respiration (*j*), or a sudden inspiratory gasp (*k*) are associated with a drop in blood pressure more frequently than with a rise, and here again, strong voluntary respirations of similar types occasion similar effects.[15] Other types of

[15] No difference was noted in the galvanic reactions after various types of voluntary respiration.

respiratory change (*e*, *f*, *g*, *h*) do not manifest these differences to so great a degree. From the lower portion of Table V it is evident that those respiratory changes most frequently accompanying a rise in blood pressure occur also with high frequency following the disturbing ideational stimuli; while those most frequently associated with a drop in blood pressure are most numerous following the sensory stimuli. This suggests, although it does not prove, that the respiratory changes typical of the various stimuli are causal factors in the differences in blood pressure which have been noted. But that these changes are only factors in, and not the sole cause of, the differences is apparent from Table VI. Here are given data on all instances available for comparison where there was no respiratory change following the stimulus.

TABLE VI

BLOOD PRESSURE AND GALVANIC CHANGES WITHOUT OBSERVABLE RESPIRATORY DISTURBANCE

(The table shows, except in the case starred, the characteristic differences between disturbing ideational and sensory stimuli)

(1) Sensory Stimuli			(2) Disturbing Ideational Stimuli			(3) Indifferent Ideational Stimuli			Column (2) Minus (1)		Column (2) Minus (3)	
N	G.	B.P.	N	G.	B.P.	N	G.	B.P.	G.	B.P.	G.	B.P.
2	.9*	1.75	7	1.77*	2.60	11	.37	1.38	1.68	.85	1.40	1.22
3	18.33	.83	3	15.97	1.97	5	7.52	.62	−2.36	1.14	8.45	1.35
6	3.03	.28	5	2.04	.86	2	1.20	1.18	− .99	.58	.84	−.32
1	4.60	.80	2	2.95	1.30	1	1.90	1.70	−1.65	.50	1.05	−.40
3	1.43	.63	3	.50	1.83				− .93	1.20		

These data are selected only from pneumographic records which show great sensitivity to bodily movement; and if respiratory changes were present it seems reasonable to believe that they were too slight to affect either the galvanic reflex or blood pressure. The fact that in all five instances the blood pressure rise is considerably greater after the disturbing ideas than after the sensory stimuli, while in every case but one the galvanic reaction is smaller under the former than under the latter condition, argues strongly that factors other than respiration contribute to the results.

TABLE VII

AVERAGE BLOOD PRESSURE AND PULSE CHANGES FOLLOWING VARIOUS STIMULI

(The table shows, except in the case starred, greater average blood pressure and higher pulse after ideational than after sensory stimuli)

Subj.	(1) Sensory No.	Ave. B.P.	Ave. Pulse	(2) Disturbing No.	Ave. B.P.	Ave. Pulse	(3) Indifferent No.	Ave. B.P.	Ave. Pulse	Differences Cols. 2–1 B.P.	Cols. 2–1 Pulse	Cols. 2–3 B.P.	Cols. 2–3 Pulse
1	23	0.59 ±0.53	0.33 ±0.05	13	3.19 ±0.35	1.52 ±0.04	23	2.85 ±0.25	0.12 ±0.03	+2.60 ±0.64	+1.19 ±0.06	+0.34 ±0.43	+1.40 ±0.05
2	11	+1.41 ±0.34	0.04 ±0.07	16	4.81 ±0.35	0.43 ±0.05	8	5.38 ±1.02	0.18 ±0.05	+3.40 ±0.49	+0.39 ±0.09	−0.57 ±1.07	+0.25 ±0.07
3	17	2.25 ±0.39	0.47 ±0.51	12	+6.58 ±1.06	0.51 ±0.12	21	1.83 ±0.50	0.96 ±0.08	+4.33 ±1.13	+0.04 ±0.19	+4.75 ±0.17	−0.45 ±0.15
4	22	−0.55 ±0.28	0.11 ±0.07	16	2.45 ±0.22	1.46 ±0.06	25	1.01 ±0.14	0.18 ±0.06	+3.00 ±0.36	+1.35 ±0.09	+1.44 ±0.26	+1.28 ±0.08
5	19	0.50 ±0.48	0.13 ±0.09	12	5.33 ±0.76	0.60 ±0.09	21	2.17 ±0.30	0.30 ±0.05	+4.83 ±0.90	+0.47 ±0.13	+3.16 ±0.82	+0.30 ±0.10
9	19	1.22 ±0.11	0.17 ±0.05	11	2.76 ±0.19	0.34 ±0.04	9	1.14 ±0.13	0.23 ±0.07	+1.54 ±0.22	+0.17 ±0.06	+1.62 ±0.23	+0.11 ±0.08
11	8	−0.88 ±0.53	−0.01 ±0.08	9	1.63 ±0.17	0.15 ±0.08	10	0.92 ±0.14	0.66 ±0.13	+2.51 ±0.56	+0.16 ±0.12	+0.71 ±0.22	−0.51 ±0.15
12	11	1.89* ±0.13	0.16* ±0.06	9	1.86* ±0.17	0.13* ±0.03	10	1.70 ±0.19	0.17 ±0.06	−0.03* ±0.22	−0.03* ±0.07	+0.16 ±0.25	−0.04 ±0.09
17	9	1.53 ±0.54	0.23 ±0.05	8	2.38 ±0.50	0.39 ±0.09	0			+0.85 ±0.74	+0.16 ±0.10		
8	16	0.81 ±0.49	0.06 ±0.04	11	2.89 ±0.50	0.19 ±0.05	0			+2.08 ±0.49	+0.13 ±0.06		

Pulse changes and blood pressure after various stimuli. The activity of the heart under various forms of excitation is here considered because it is one of the most important factors in blood pressure. Changes in pulse rate, as determined by the number of heart beats during the five seconds following the beginning of the blood pressure change, minus the number of beats in the five seconds preceding the stimulus, is probably the best general index here available of the change in cardiac activity due to excitation. While it is true that the force and degree of filling of the heart also affect blood pressure, these factors are not indicated in the record with the same certainty as changes in frequency. Although the height of the pulse and the nature and position of the dicrotic notch may be indicators of cardiac activity, they are affected also by vasomotor changes, and the mechanics of registration.[16] Only frequency as indicated by pulse rate is in this respect largely free from ambiguity of interpretation. Effects of various stimuli upon heart rate show in Table VII an average acceleration as well as an average rise in blood pressure following all stimuli, and indicate that both of these changes are greater after ideational than after sensory stimuli.

TABLE VIII

PERCENTAGE OF REACTIONS ACCOMPANIED BY MINUS B.P. AND PULSE CHANGES

(The table shows, except in the case starred, a larger percentage of minus B.P. and pulse changes after sensory than after disturbing ideational stimuli)

	Sensory			Disturbing			Indifferent		
Subj.	N	Minus B.P. Changes %	Minus Pulse Ch'gs %	N	Minus B.P. Ch'gs %	Minus Pulse Ch'gs %	N	Minus B.P. Ch'gs %	Minus Pulse Ch'gs %
1	23	34.8	0.0	13	0.0	0.0	23	8.7	4.3
2	11	9.1	45.5	16	0.0	0.0	8	0.0	25.0
3	17	23.6	29.4	12	0.0	16.7	21	23.8	28.6
4	22	50.0	40.9	16	0.0	25.0	25	8.0	32.0
5	19	20.0	36.8	12	0.0	8.3	21	4.8	19.1
8	16	56.2	43.8	11	18.2	27.2	6	33.3	16.7
9	19	00.0	15.8	11	0.0	9.1	9	0.0	33.3
11	8	62.5	62.5	9	0.0	22.2	10	10.0	30.0
12	11	0.0	36.4	9	0.0	22.2	10	0.0	30.0
17	9	22.2	11.1*	8	12.5	25.0*	5	0.0	25.0

[16] K. Hürthle, Beiträge zur Hämodynamik; Kritik des Lufttransmissionsverfahrens. *Pflügers Arch. f. d. ges. Physiol.*, 1892–1893, 53, 281–331.

TABLE IX

CORRELATION (r) OF BLOOD PRESSURE, PULSE, AND GALVANIC CHANGES

(The table shows positive correlations between pulse and blood pressure following ideational stimuli (one exception: Columns 6 & 10) and, except in two instances, low or negative correlations following sensory stimuli; Column 2)

	Sensory Stimuli				Disturbing Ideat'al Stimuli				Indifferent Ideat'al Stimuli			
	1	2	3	4	5	6	7	8	9	10	11	12
Subj.	B.P. with G.	B.P. with P.	G. with P.	B.P. with G. partial out P.	B.P. with G.	B.P. with P.	G. with P.	B.P. with G. partial out P.	B.P. with G.	B.P. with P.	G. with P.	B.P. with G. partial out P.
1	−.347	.186	−.197	−.322	−.030	.549	.268	−.220	.004	.483	−.113	.067
2	.285	.326	.268	.409	−.006	.501	.027	−.002	.236	−.162*	.436	.345
3	.555	.093	.366	.562	.152	.323	.156	.109	.650	.425	.367	.587
4	−.062	.015	−.011	−.062	.082	.422	.132	.029	.476	.507	.152	.469
5	−.543	−.273	−.073	−.586	.648	.527	.483	.528	.045	.395	−.003	.051
8	.361	.072	.055	.359	−.017	.760	−.004	−.021	Few measurable reactions			
9	.377	.391	.310	.292	−.186	.805	−.136	−.129	.754	.406	.552	.696
11	.116	−.279	.081	.145	.419	.521	.074	.447	.416	.588	.016	.502
12	−.233	.619	.118	−.393	.382	.314	.465	.281	.067	.207	.629	.083
17	−.688	−.528	.931	−.635	.577	.830	.333	.572	Few measurable reactions			

The question whether there is a consistent causal relation between pulse rate and blood pressure is probably best approached by the method of correlation. In Table IX are correlations between the magnitudes of blood pressure and pulse changes following various types of stimuli. Only in the case of the disturbing ideational stimuli are these coefficients consistently positive, ranking as they do from .314 to .837, with an average value of .555. This tendency toward a positive *r* between pulse and blood pressure is also generally present—save for one exception—in the case of the indifferent ideational stimuli. On the other hand, sensory excitation shows no consistent relationship between these measures, about an equal number of individuals giving positive, negative, and approximately zero correlations. Whether or not this represents some basic physiological or personality difference or is due to chance or insignificant factors is a problem which may repay further study. The same is true of the fact that some individuals here manifest a tendency toward a strongly positive *r* between blood pressure and the galvanic reflex while others show an equally strong tendency in the other direction.

Cutaneous secretory changes. Among the other bodily reactions differentially affected by these stimuli, mention should be made of the momentary increase in the secretion of the sweat glands that occurs after any moderately strong excitation. In planning this study the close correlation that had already been demonstrated between the magnitudes of electrical and secretory changes [17] was a basis for assuming that little of further significance would be added by complicating the records with an additional tracing of moisture changes. In support of this assumption the cutaneous secretory reactions of a few subjects are given in Table X. These results indicate the consistency with which sensory stimuli occasion relatively greater moisture change for a given rise in blood pressure, or relatively smaller blood pressure rise for a given secretory change than do disturbing ideational stimuli.

[17] Concerning previous study *cf.* note 5, p. 269.

TABLE X

AVERAGES OF MOISTURE AND BLOOD PRESSURE CHANGES FOLLOWING DIFFERENT TYPES OF STIMULATION

(The table shows the consistency with which disturbing ideational stimuli occasion relatively greater blood pressure rise for a given secretory change than sensory stimuli.)

Subj.	Total N	(1) Sensory Stimuli			(2) Disturbing Ideational Stimuli			(3) Indifferent Ideational Stimuli			Column (2) Minus (1)		Column (2) Minus (3)	
		N	M.	B.P.	N	M.	B.P.	N	M.	B.P.	M.	B.P.	M.	B.P.
16	18	7	2.4	1.7	6	.9	2.9	5	1.3	1.6	− 1.5	1.2	−0.4	1.3
18	21	9	18.9	3.0	7	19.1	5.9	5	8.1	2.9	0.2	2.9	11.0	3.0
23	7	2	13.0	1.3	3	13.8	5.2	2	8.0	1.8	0.8	3.9	5.8	3.4
24	26	12	12.3	5.2	9	5.4	4.8	5	6.8	3.4	− 6.9	−0.4	−1.4	1.4
25	17	6	11.1	2.9	6	6.1	2.9	5	6.8	2.9	− 5.0	0.0	−0.7	0.0
26	15	7	10.5	4.4	6	6.5	8.1	2	4.4	6.3	− 4.0	3.7	2.1	1.8
27	8	3	3.8	2.3	4	3.0	3.0	1	4.5	2.2	− 0.8	0.7	−1.5	0.8
Total			72.0	20.8		54.8	32.8		39.9	21.1	−17.2	12.0	14.9	11.7
Ave.			10.3	3.0		7.8	4.9		5.7	3.0	−2.5	1.7	2.1	1.7
Ave. Dev.			4.1	1.1		4.9	1.5		2.0	1.0	2.4	1.5	3.6	0.9

Because of differences in the strength of the various stimuli a comparison of the absolute size of the galvanic and blood pressure reactions is here less convincing than a comparison of the relative sizes of these measures; *e.g.* $\frac{\text{blood pressure change}}{\text{moisture change}}$. Thus in the case of Subj. 24 we may compare $\frac{5.2}{12.3}$ with $\frac{4.8}{5.4}$, and note how much larger is the ratio of the blood pressure to the galvanic change in the second case.

Vasoconstriction in relation to other changes. A study of patterns of circulatory and cutaneous electrical changes following various stimuli would be incomplete without a consideration of vasomotor phenomena. Not only may an alteration of the lumen of the smaller blood vessels be an important factor in determining blood pressure, but its possible effect upon the electrical conductivity of the skin may constitute it a peripheral mechanism affecting the relative magnitudes of these two measures.

In the present investigation simultaneous records of volume change in the fingers, of blood pressure, and of the gal-

vanic reflex have been made in the effort to determine the interrelationships. The apparatus used consisted of two plethysmographs connected above by air conduction with a delicate tambour. When these plethysmographs were filled with dilute salt solution they also served as two liquid electrodes, and the galvanic reflex could be obtained from the same areas which gave records of vasomotor changes.[18]

A blood pressure record taken simultaneously from the opposite arm eliminates the possibility of mistaking an altered volume due to change of internal pressure for one due to vasomotor activity.

Readings of finger volume and blood pressure change are made for the three intervals, (*a*) during the latent period from the stimulus to the beginning of the galvanic reflex, (*b*) during the rise of the galvanic curve, and (*c*) during the period of recovery or drop of the galvanic curve from peak to point of flexion toward the prevailing base-line. The data given in Table XI*a* show a considerable tendency for the fingers to become larger during the latent period and initial rise of the galvanic reaction, and a rather consistent tendency for them to become markedly smaller during the recovery of electrical equilibrium.[18a] The change in finger volume is, however, accompanied by a greater blood pressure rise or smaller blood pressure drop in the case of ideational than in the case of sensory stimuli. As a result, even were the active vasomotor factor the same after the two stimulating conditions, their respective volume changes would be different. In the attempt to obviate the effect of blood pressure upon volume and to determine differences in the active vasomotor change, selected pairs of reactions to sensory and ideational stimuli have been chosen in which blood

[18] Since two homologous portions of the body are here connected, a continuous source of external current and a wheatstone bridge are employed. A more detailed description of the apparatus, sample records, and evidence that variations in the volume of the fingers bear no necessary relation to the electrical changes are to be found in The galvanic skin-reflex and finger volume changes, *Amer. J. Physiol.*, 1929, *88*, 219–229.

[18a] In a large proportion of cases the increase in size of the fingers is accompanied by, and is possibly a result of, increased blood pressure (cf. last preceding foot note).

TABLE XIa

THE EFFECTS OF VARIOUS STIMULI UPON VOLUME CHANGES

(The table shows a slight tendency toward increased volume of the fingers during and preceding the initial galvanic deflection and a markedly decreased volume during the recovery of electrical equilibrium)

		Sensory Stimuli						Ideational Stimuli															
			During Galvanic Latent Period		During Initial Galvanic Deflection		During Return toward Electrical Equilibrium			During Galvanic Latent Period		During Initial Galvanic Deflection		During Return toward Electrical Equilibrium		DIFFERENCE Ideational minus Sensory Conditions: During Galvanic Latent Period		During Initial Galvanic Deflection		During Return Electrical Equilibrium		TOTAL DIFFERENCE Ideational minus Sensory		
Subj.	N.	Galv. Chng.	V.	B.P.	V.	B.P.	V.	B.P.	N.	Galv. Chng.	V.	B.P.	V.	B.P.	V.	B.P.	V.	B.P.	V.	B.P.	V.	B.P.	Galv. Chng.	V.	B. P.
66	12	13.87	+0.28	−0.45	−0.21	+0.51	−1.57	−0.38	12	8.25	+0.47	−0.08	+0.77	+1.83	−1.68	+1.85	+0.19	+0.37	+0.98	+1.32	−0.11	+2.23	−5.62	+1.06	+3.92
67	11	14.49	+0.80	+0.58	−0.14	+1.29	−1.45	−2.51	15	1.25	+0.48	+0.19	+0.41	+2.27	−1.04	−0.41	−0.32	−0.39	+0.55	+0.98	+0.41	+2.10	−13.24	+0.64	+2.69
68	13	5.12	−0.68	−0.43	+0.38	−0.03	−0.55	−1.55	13	1.93	−0.07	+0.57	+0.16	+1.44	−0.22	−2.33	+0.61	+1.00	−0.22	+1.47	+0.33	−0.78	−3.19	+0.72	+1.69
69	9	18.73	+0.27	+0.09	−0.83	+1.86	−9.22	−2.49	13	1.40	+1.31	+0.61	+0.75	+0.65	+0.98	−1.52	+1.04	+0.52	+1.58	−1.21	+10.20	+0.97	−17.33	+12.82	+0.28
70	14	8.84	+0.37	−0.24	+0.32	+1.34	−1.53	−1.04	13	2.77	−3.54	+0.93	+0.62	+2.59	−1.52	−1.43	−3.91	+1.17	+0.30	+1.25	+0.01	−0.39	−6.07	−3.60	+2.03
71	15	2.99	+0.27	+0.60	−0.85	+1.33	−3.87	−1.28	10	1.10	+0.27	−0.02	0.00	+0.90	−2.92	−1.10	0.00	−0.62	+0.85	−0.43	+0.95	+0.18	−1.89	+1.80	−0.87
72	13	6.31	+0.19	−0.71	−0.48	−0.53	−0.15	−0.68	21	0.17	+0.12	+0.42	−0.23	−0.52	−0.15	−1.47	−0.07	+1.13	+0.25	+0.01	0.00	−0.79	−6.14	+0.18	+0.35
73	10	6.32	−1.05	−0.20	−0.18	+0.14	+0.71	−1.08	14	0.86	−0.29	−0.32	−0.36	+0.17	−0.31	−0.46	+0.76	−0.12	−0.18	+0.03	−1.02	+0.62	−5.46	−0.44	+0.53
74	17	10.40	−0.14	−0.74	−0.36	−0.06	−1.24	−0.59	21	6.84	+0.19	+0.60	−0.12	+2.70	−1.94	−1.76	+0.33	+1.34	+0.24	+2.76	−0.70	−1.17	−3.56	−0.13	+2.93
75	7	31.71	+0.93	−0.06	+0.99	+3.56	−4.37	−2.97	9	5.84	+0.86	+1.13	+0.70	+1.91	−1.42	−2.11	−0.07	+1.19	−0.29	−1.65	+2.95	+0.86	−25.87	+2.59	+0.40
76	10	1.65	+0.17	+0.53	−0.83	+0.23	−5.34	−2.26	3	0.17	+0.67	+2.60	−1.90	−1.30	−2.93	−2.53	+0.50	+2.07	−1.07	−1.53	+2.41	−0.27	−1.48	+1.84	+0.27
77	9	8.95	+0.01	−0.32	−0.38	+0.48	−0.01	−2.01	5	8.94	+0.66	−0.18	−0.18	+0.04	−0.12	−0.26	+0.65	+0.14	+0.20	−0.44	−0.11	+1.75	−0.01	+0.74	+1.45
78	7	0.80	+0.23	−0.10	−2.29	−0.09	−2.87	−0.39	6	0.65	−0.10	−0.42	−0.70	+3.05	−4.68	−0.85	−0.33	−0.32	+1.59	+3.14	−1.81	−0.46	−0.15	−0.55	+2.36
Ave.		10.01	+0.13	−0.11	−0.37	+0.77	−2.42	−1.48	Ave.	3.09	+0.08	+0.46	−0.01	+1.21	−1.38	−1.10	−0.06	+0.58	+0.37	+0.44	+1.04	+0.37	−6.92	+1.36	+1.39

N. = Number of Reactions.
Galv. Chng. = Galvanometer Change.
V. = Volume Change.
B.P. = Blood Pressure Change.

These figures represent only the change during the prescribed interval. Each change must be added to the preceding changes to determine total effects.

TABLE XI*b*

THE EFFECTS OF VARIOUS STIMULI UPON VOLUME CHANGES WITH BLOOD PRESSURE HELD CONSTANT

(The table shows that when reactions having equal blood pressures are compared the volume of the fingers tends to be more markedly decreased or less markedly increased after sensory than after ideational stimuli)

		During Galvanic Latent Period (From Stimulus to Initial Deflection)									During Initial Galvanic Deflection (From Initial Deflection to Peak of Curve)									During Return toward Electrical Equilibrium (From Peak to Flexion toward Base Line)								
		Sensory Stimuli			Ideational Stimuli			Difference: Ideational minus Sensory			Sensory Stimuli			Ideational Stimuli			Difference: Ideational minus Sensory			Sensory Stimuli			Ideational Stimuli			Difference: Ideational minus Sensory		
Subj.	N.	Galv. Chng.	V.	B.P.	Galv. Chng.	V.	B.P.	Galv.	V.	B.P.	N.	Galv. Chng.	V.	B.P.	Galv. Chng.	V.	B.P.	Galv.	V.	B.P.	N.	Galv. Chng.	V.	B.P.	Galv. Chng.	V.	B.P.	Galv.	V.	B.P.
66	4	9.55	+0.40	−0.10	7.00	−0.05	−0.10	−2.55	−0.45	Ap-	4	16.25	+0.43	+0.25	4.45	+0.55	+0.23	−11.80	+0.12	Ap-	4	8.70	−1.50	−0.25	8.30	−1.20	−0.25	−0.40	+0.30	Ap-
67	4	15.80	+0.63	+0.30	1.35	+0.60	+0.28	−14.45	−0.03	proxi-	5	15.92	+0.40	+1.92	2.12	+0.40	+1.92	−13.80	0.00	proxi-	4	16.50	−1.85	+0.55	0.85	−0.55	+0.55	−15.65	+1.30	proxi-
68	5	5.54	−0.64	+0.56	1.20	−0.28	+0.56	−4.34	+0.36	mate-	5	5.68	+0.12	+0.46	2.62	+0.16	+0.48	−3.06	+0.04	mate-	5	3.68	−0.64	−1.96	2.26	+0.04	−1.94	−1.42	+0.68	mate-
69	2	14.70	+1.90	+1.50	0.40	+3.10	+1.50	−14.30	+1.20	ly	3	13.13	−1.37	−0.07	0.40	+0.73	−0.10	−12.73	+2.10	ly	4	18.65	−6.70	−2.15	0.35	+0.25	−2.15	−18.30	+6.95	ly
70	6	11.80	+0.65	+0.20	2.60	−0.70	+0.18	−9.20	−1.35	0.00	4	10.20	+0.23	+1.55	1.45	+0.75	+1.58	−8.75	+0.52	0.00	4	6.45	−2.15	−0.50	2.40	−0.50	−0.50	−4.05	+1.65	0.00
71	3	2.33	−0.80	−0.67	1.20	+0.97	−0.67	−1.13	+1.77		3	2.43	−0.90	+0.80	0.93	−0.67	+0.77	−1.50	+0.23		4	3.60	−3.75	−0.15	0.78	−1.75	−0.15	−2.82	+2.00	
72	6	3.30	−0.07	−0.10	0.40	+0.10	−0.12	−2.90	+0.17		10	4.88	−0.36	−0.66	0.28	−0.22	−0.66	−4.60	+0.14		7	4.28	−0.33	−0.86	0.40	−0.16	−0.86	−3.88	+0.17	
73	5	7.10	−0.78	−0.04	0.86	−0.74	−0.06	−6.24	+0.04		5	5.50	−0.16	+0.08	0.70	−0.34	+0.08	−4.80	−0.18		5	5.56	+0.82	−0.90	0.96	+0.36	−0.90	−4.60	−0.46	
74	9	9.70	−0.25	−0.59	6.08	+0.10	−0.58	−3.62	+0.35		6	11.00	−0.17	+2.32	6.33	−0.35	+2.33	−4.67	−0.18		8	9.50	−1.37	−1.71	5.40	−1.44	−1.71	−4.10	−0.07	
75	3	30.00	+1.33	+2.00	5.13	+1.10	+2.03	−24.87	−0.23												2	29.60	−5.00	−2.20	15.30	−4.60	−2.20	−14.30	+0.40	
76	2	2.05	−0.05	+2.00	0.00	+0.30	+2.00	−2.05	+0.35		2	1.50	−1.20	−1.00	0.00	+0.10	−1.00	−1.50	+1.30											
77	3	8.13	+0.17	−0.07	12.57	−0.07	−0.03	+4.44	−0.24		3	18.00	−0.97	+0.30	12.57	−0.27	+0.33	−5.43	+0.70											
78																					2	0.85	−4.20	+0.99	0.20	−5.35	+0.95	−0.65	−1.15	
					Average Difference			−6.77	+0.16	0.00					Average Difference			−6.60	+0.44	0.00					Average Difference			−6.38	+1.07	0.00

N. = Number of Reactions.

Galv. Chng. = Galvanometer Change.

V. = Volume Change.

B.P. = Blood Pressure Change.

pressure changes were approximately the same, and differences in the vasoconstriction under the two stimulating conditions have been noted. It is apparent from Table XI*b* that, even with blood pressure constant, there are larger negative and smaller positive changes in volume in the case of sensory than in the case of ideational stimuli.

Summary

The results of this study may be summarized in the following statements.

1. Blood pressure and the galvanic skin-reflex may vary independently.
2. There is a general tendency for sensory stimuli to occasion larger galvanic and smaller blood pressure changes than disturbing ideational stimuli and, conversely, for disturbing ideational stimuli to occasion larger blood pressure rise and smaller galvanic changes than sensory stimuli.
3. There is a general tendency for disturbing ideational stimuli to occasion larger blood pressure and galvanic changes than indifferent ideational stimuli, and for this difference, as measured by percentage of the total change or as compared with the P.E. of the difference, to be greater for the former than for the latter measure.
4. Respiratory reactions tend to be different following the various stimuli and to be of such a character that they may contribute to differences in blood pressure.
5. Cardiac activity as indicated by pulse rate is increased more consistently by ideational than by sensory stimuli.[19]
6. Cardiac activity as shown by the method of correlation is probably a consistent factor in the increased blood pressure occasioned by ideational stimuli but not in that caused by sensory stimuli.
7. Vasoconstriction as indicated by decreased peripheral volume is more marked following sensory than after ideational stimuli.[20]

These results are summarized in Table XII.

[19] See note A below Table XII.

[20] See note B below Table XII.

TABLE XII

THE ABSOLUTE AND RELATIVE EFFECTS OF STIMULI UPON VARIOUS MECHANISMS

Mechanism	Absolute Effect Typical of Sensory Stimuli	Relative Value	Absolute Effect Typical of Dis-t'bing Ideat'al Stimuli	Relative Value	Absolute Effect Typical of In-diff't Ideat'al Stimuli
Blood Pressure.....	±	<	+	>	+
Pulse.....	±	<	+	>	+
Galvanic Reflex (conductivity).....	+	>	+	>	+
Perspiration.....	+	>	+	>?	+
Vasoconstriction (volume).....	−	>	−	>?	−

? Not demonstrated in this study.

A. Exceptions. Certain general exceptions to these principles found in the literature may be mentioned.

(1) The fact that disturbing ideas occasioning extreme unpleasantness or depression may slow the heart rate

(2) the fact that tastes and smells (see note, p. 272), though sensory stimuli, as a rule occasion increased rather than decreased frequency (except where irritation of the trigeminal nerve is involved)

(3) the fact that continuous prolongation of sensory stimuli is likely to be accompanied by increased heart rate, and

(4) the fact that fright or extreme startledness following sensory stimuli is likely to be accompanied by a momentary increase in pulse rate preceding the characteristic slowing.

None of these situations, save in some instances the last, is characteristic of the experimental conditions of this study; yet some evidence relating to these stimuli has been given in reviewing the literature.

B. On account of the difficulty involved in obtaining satisfactory records of vasomotor changes in the splanchnic region this factor in peripheral blood pressure has not been controlled. Such evidence as is available is presented in the review.

DISCUSSION OF RESULTS

The results presented are likely to suggest at once certain factors which might account for them. These factors will be briefly discussed.

1. The '*startling*' *character* of certain stimuli. It may be suggested that the differences between reactions to 'sensory' and 'ideational' stimuli are due not to the sensory character of one stimulus as contrasted with the sensory-plus-ideational character of the other but to the presence of the element of *choc* or startledness in the case of the sensory and its absence in the ideational situations. It is to be kept in mind, however, that the moment of excitation is unknown in the case of all stimuli,[21]

[21] See note, p. 272.

and that, so far as the element of surprise or unexpectedness is concerned, one situation should be as startling as the other. Some subjects even reported the verbal stimuli to be the more startling of the two conditions.

2. The *specific nerves* stimulated. That the results might be explained as due to the stimulation of specific peripheral nerves which, because of their anatomical connections, occasion certain physiological effects is to be questioned. In the first place, a comparison of two types of stimuli affecting the same nerves, *e.g.* auditory sensory and auditory ideational stimuli, shows the typical differences in reaction. Furthermore, the specific possibility that trigeminal areas, the excitation of which tends to inhibit cardiac activity, are more often stimulated by sensory than by ideational stimuli seems to be eliminated as a determining factor. The fact that sensory stimuli on parts of the body other than the head produce typical reactions favors this conclusion.

3. The *physiological intensity* of the stimuli. That these results are a function of the physiological intensity of the stimuli is suggested because work on direct nerve stimulation of animals under anæsthesia has sometimes shown weak stimuli to occasion an increase and strong stimuli a decrease in heart rate.[22] If a similar effect occurs on the pulse and blood pressure of the waking human being, and if the galvanic reflex is at all an index of the physiological intensity of the stimuli, then we should expect a negative correlation between blood pressure and the galvanic reflex. It will be noted, however, in Table IX that only in the case of a few subjects is this the tendency. Furthermore, according to this principle indifferent ideational stimuli which are relatively weak and show small galvanic reactions should have a large pulse rate and blood pressure increase, and this is not the case.

4. The *psychological intensity* of the stimuli. The possibility should also be considered that the results presented are functions of some aspect of psychological intensity such as the degree of attention or 'excitement' or 'tension' aroused (or relieved) by the coming of the respective stimuli. If 'disturbing ideational' stimuli be regarded as occasions for fear, resentment or effort on the part of the subject, then, from results found in other studies, their occurrence should be accompanied by increased blood pressure and galvanic change. The intervention of sensory or indifferent ideational stimuli in such a series of disturbing situations would presumably constitute an occasion for momentary relief from the tension of anticipation, and might therefore cause a drop in blood pressure. It would also occasion smaller galvanic change. In order to account for the large galvanic reactions following sensory stimuli we should have to show, according to this theory, that larger electrical changes were produced by relief or reduced tension than by excitation, and this is, of course, contrary to the facts. We should then have to explain the fact that indifferent ideational stimuli, which presumably also involve relief, occasion smaller galvanic responses than disturbing ideational situations. While differences in the physiological responses to varying degrees of attention, tension and relaxation, excitement and calm, and even of pleasantness and unpleasantness are reported by various investigators, no one of these psychological conditions appears to account for all of the results.

5. The *duration* of the *objectively effective* stimulus. That the results might be attributed to some difference in the duration of the objective stimuli—the sensory situation, on the one hand, tending to be short and momentary; a word or a phrase on the other hand, tending to affect the sense organ over a longer period—seems doubtful under the conditions of this experiment. This might be a factor in the cases

[22] See Stewart, Manual of physiology, p. 171.

where phrases instead of monosyllabic words were used as stimuli; but examination of the results indicates little relation between the duration of the verbal stimulus and the magnitude of the reactions to ideational stimuli. Furthermore, single short words, such as 'sex,' 'love' and 'kiss,' which are comparable in brevity to the sensory stimuli that were employed show the same differences manifested by polysyllabic words and phrases.

6. The *duration* of the *subjectively effective* stimulus.[23] Of probably greater significance are the differences in the duration of the subjectively effective stimuli. Ideas occasioned by the stimuli tend to persist for a much longer time than mere sensory effects. This constitutes an intrinsic difference between sensory and ideational conditions, a difference which is characteristic of them according to the original definition and description of the stimuli on page 278. If perfect experimental conditions were possible, the subjectively effective stimulus would *always* outlast the effects due to the sensory excitation occurring at its initiation. Evidence from other investigations showing that prolonged sensory stimuli and rapidly repeated stimulation of nerves likewise generally cause a rise in blood pressure suggests that the duration of the subjectively effective stimulus is an important factor in these results.

7. The *difference between habitual and random reactions.* The results might be neurologically accounted for by the assumption that in the case of ideational stimuli there is a drainage of the effects of the initial sensory situation into paths of habitual ideational response; while in the case of sensory stimuli there is diffusion or irradiation because such paths are lacking. Such a difference in reactions perhaps implies a difference in the functional level of neural activity involved in the two situations. Perhaps the difference is further analogous, with respect to the effectors, to that alleged between protopathic and epicritic sensations in the case of receptors. The fact that cardiac activity is normally modified in the adjustive activities of daily life is possibly a reason for expecting that somewhat similar modifications of that activity would occur when adjustment takes place upon an ideational or language level. To test and possibly to apply this hypothesis is one of the aims of further study.

The canvas of the various possible factors contributing to the results presented in this report leaves the impression that two important factors contribute to differentiate the reactions to sensory and ideational stimuli; (1) the duration of the 'subjectively effective' stimulus and (2) the functional neural levels probably involved. The degree to which the subject is startled (the 'shock') may differ under ideational and sensory conditions, but probably not because of differences in the unexpectedness, intensity, or duration of the objective conditions, but because impulses aroused by momentary sensory stimuli find no ready outlet in habitual reaction mechanisms as they do in the case of ideational stimuli. Shock and surprise and their accompanying peripheral changes

[23] 'Subjectively effective,' as used in contrast to 'objectively effective' in 5. It is implied by this term that the subject's report of his ideational processes indicated the continuation of associations initiated by the stimulus.

thus appear to be due, in the negative sense, to the lack of organization for appropriate response, or perhaps to the want of an adequate mechanism for delaying the reaction.

Conclusions

The preceding experimental study and a review of the literature published elsewhere (see summary, p. 296 above) lead to the following general conclusions.

1. There are two physiologically as well as psychologically distinguishable processes which have frequently been designated as 'emotion,' namely, the immediate reflex response to sensory excitation, and the response mediated by associative processes or ideas aroused by the stimulus.

2. A comparison of the immediate reflex effect of sensory stimuli with the effect mediated by associative or ideational processes shows that the former is relatively more effective in producing changes in peripheral mechanisms such as those of vasoconstriction, perspiration or the galvanic skin-reflex, while the latter is relatively more effective in increasing cardiac activity as indicated by blood pressure or pulse rate.

3. Shock or surprise with its attendant galvanic reaction is probably occasioned by irradiation of the excitation due to the momentary lack of adequate neural organization for delayed or appropriate response.

4. Blood pressure, under the conditions of this experiment, differentiates better between 'disturbing' and 'indifferent' ideational stimuli than does the galvanic skin-reflex.

(Manuscript received October 20, 1928)

THE QUANTITATIVE SET

BY ARTHUR GILBERT BILLS AND CLARENCE BROWN

University of Chicago

One of the most important factors determining the level of efficiency which an individual may attain in mental work is the attitude or set with which he enters upon the task. The fact has for some time been recognized in studies on the work curve, and has been offered as a reason for the low correlation between level of output and capacity as measured by the usual methods. But more effort has been directed toward controlling attitude as a disturbing variable than toward studying it for its own sake. As a result little is known regarding the quantitative influence of set in mental work.

To begin with, there are innumerable kinds of set. One kind is the social set, as opposed to the solitary. Allport and others have demonstrated differences due to group attitude, even when competition is not implied. Another kind of set is contributed by knowledge of one's previous efforts, and the desire to compete with oneself. Another is the set which the experimenter, intentionally or unintentionally, imparts to the subject when he gives directions. Again, the prejudices which the subject brings to the experiment constitute a determining set. And still another example is the fact that a subject who has been working previously at a fast or slow rhythm will enter the subsequent task with that speed set, and his output will vary accordingly.

In the series of investigations to be reported, the aim was to determine to what extent an individual's efficiency is influenced by the amount of work with which he is faced. This we have named, for want of a better term, the 'quantitative set.' Will an individual who is faced with a long task start off at the same level and maintain the same degree of efficiency as an individual who is faced with a short task?

To answer this question, *i.e.* whether a person's level of efficiency in a task is in part a function of the particular quantity of work with which he is faced, it would be necessary to arrange a series of four or five tasks differing from one another only in the amount of work presented; and then to secure work curves on each, from a large number of subjects. If quantitative set has any influence, then the initial levels of the respective work curves ought to differ proportionally. The decrements in the several work curves might also vary in steepness relative to the quantitative set.

Two kinds of quantitative set are possible. Thus an individual may be set to work a given length of time, regardless of amount done; or he may be set to do a given amount of work, regardless of how long a time he takes. The first situation may be called a 'time set,' and the second an 'amount set.' There is no *a priori* reason for supposing that these two kinds of set would influence the work curve in the same way. Either or both may be effective, and in different degrees. The arrangement of conditions described in the preceding paragraph would give an amount set. On the other hand, a time set would be given provided the subject were always presented with the same amount of work but told, on one occasion, that he would be stopped at the end of two minutes, on another four, on another eight, etc.

In the first of the experiments to be described below, time and amount set were not differentiated. In the second, they were.

The criterion of efficiency used throughout the investigation was speed, as measured by number of examples done per minute or per quarter-minute. Errors proved negligible and were therefore disregarded.

Muscular Tension as Related to Set and Efficiency

The concept of 'set' may or may not be given definition in terms of muscular factors. But the tendency of late has been to explain it as a condition of contraction or readiness-to-act of certain muscle groups. An individual who is set to lift a heavy weight will develop a degree of preparatory

tension in his muscles different from that which he would develop if he were set to lift a light weight. Now it is possible that when an individual is set for a long or hard piece of mental work, he will assume a different degree of tension or effortfulness in preparation, and that it is this which constitutes set. Any such condition would be likely to show itself objectively. Thus if the mental work involved writing, it would show itself in the increased pressure exerted on the pencil.

Since this problem was thought worthy of investigation in connection with the present experiment, the following method was used. First, the type of work used throughout was addition of pairs of digits arranged in continuous horizontal rows on sheets of paper. The answers were written on the sheet in pencil immediately below the pairs. Underneath the sheet upon which the subject was writing the answers there were placed five thin sheets of paper with carbon papers between. The whole was pasted on a stiff cardboard back, which gave the subject a firm surface to write on. By means of this device it was possible to tell how much tension the subject had exerted on his pencil at any point in the work, by finding out how many and how clear were the carbon tracings. The aim was to determine whether there was any correlation between (*a*) the particular set and the degree of tension exerted, and (*b*) the degree of tension and the level of efficiency, at any point of the work curve. The results of this part of the study will be described separately.

Experiment I; Part A. In this first experiment, *time set* and *amount set* were not differentiated. The work consisted of adding pairs of digits arranged in continuous rows on a sheet of paper. The answers were written on the sheet immediately under the digits. A row contained forty-five examples. For each condition, the subject was presented a sheet containing enough of these rows to keep him busy as many minutes as the particular condition called for. Hence he was faced with a certain amount of work, and was also told that he was to work a certain length of time. Thus the resulting set was a combination *time-amount* set.

Four conditions were used; Condition I, in which the subject was told that he was to work one minute before stopping; Condition II, two minutes; Condition III, five minutes; and Condition IV, ten minutes.

A signal was given every quarter-minute, and a check put by the subject at the point on the page which he had reached, so that work curves could later be plotted showing the output by quarter-minutes.

Twenty subjects were used, all students of some psychological training from the University of Minnesota laboratory. The subjects reported in pairs, in this experiment, and only twice a week. The experiment therefore lasted a month.

A short practice period was run previous to the regular series; but it probably did not eliminate practice effect as a variable. Hence the method of counterbalanced order was used throughout the four conditions, as an added check. The subjects were divided into four groups, those in Group A beginning on Condition I, and taking the conditions in the order I, II, III, IV; those in Group B beginning on Condition II, and following the order II, III, IV, I, etc.; those in Group C beginning with Condition III; and those in Group D with Condition IV.

Two cycles of the main experiment were completed, so that every subject went through each condition twice.

Results

Since the shortest condition involved only one minute's work, it is possible to compare only the first minute's records for the various conditions. Not much decrement develops during the first minute, but the trend is clearly evident. The initial level is shown by the amount done during the first quarter-minute.

A statistical and graphical analysis of the results is given to answer the following questions; (1) How does the specific quantitative set influence the initial level of the respective work curves? and (2) How does the specific quantitative set influence the decrement, or drop from the initial level?

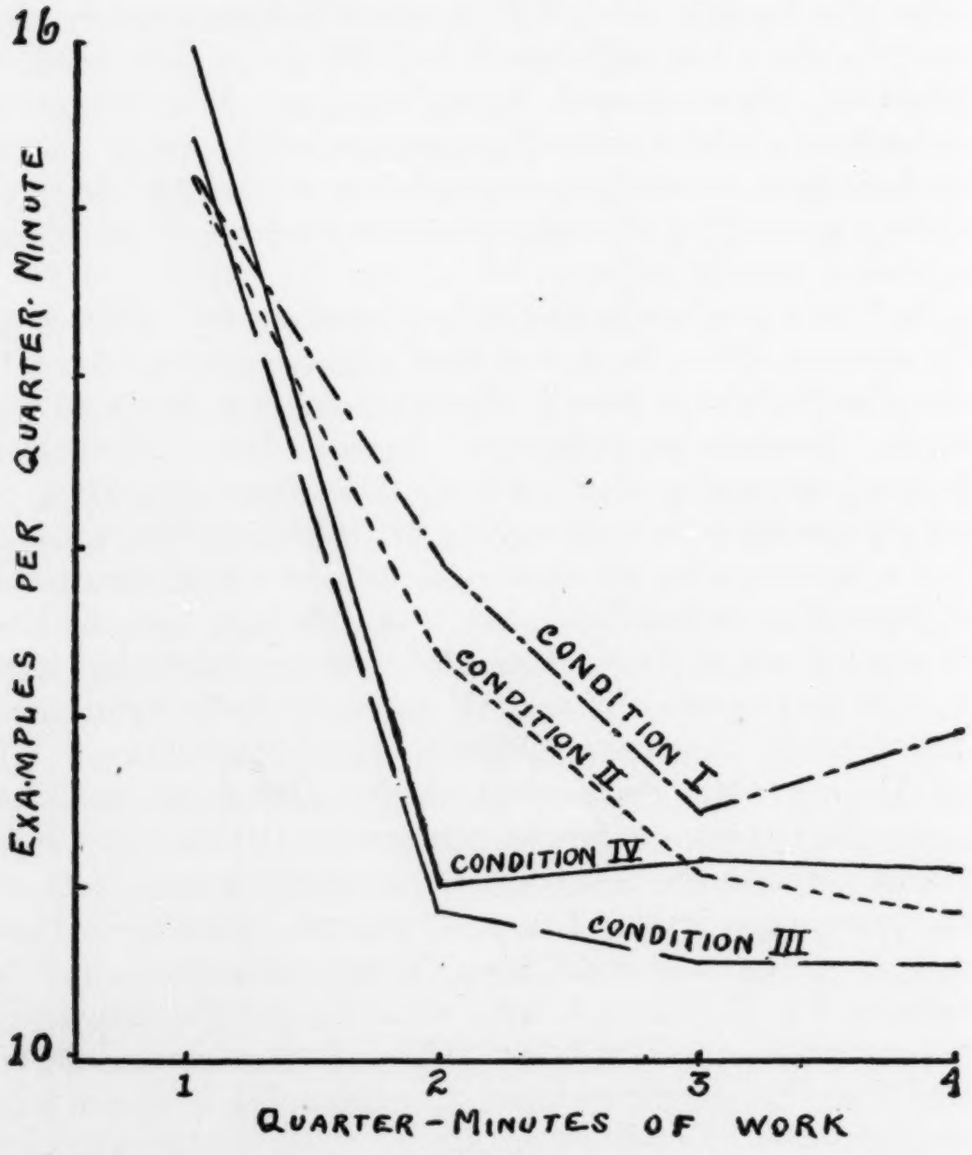
Influence of quantitative set on initial level. Table I shows the average number of additions by quarter-minutes for the first four quarter-minutes of the work curves, for each condition. Cycles I and II are averaged. If we let the initial level be represented by the score for the first quarter-minute, there is a slight tendency for it to vary directly with the condition, the longest set giving the highest initial level. The differences are too slight to be very significant in this case. For example, the P.E. of the difference between the initial levels for Conditions I and IV is as large as the difference. That there is a real tendency here, however, which is concealed by the experimental conditions, is shown by the results of our later experiments, where time set and amount set were kept separate instead of being combined as here.

Influence of quantitative set on decrement. By subtracting the amount done in the second quarter-minute of each condition from that done in the first, one can compute the relative decrements under the various quantitative sets. They are, beginning with the shortest condition, 2.3, 2.8, 4.5, and 4.9 examples per quarter-minute (Q.M.). This seems to show a tendency for the decrement to vary directly with the length of the set (see Table I). The difference between the decrements of Conditions I and III, and that between I and IV, and that between II and IV are statistically significant. That between Conditions I and II, and that between III and IV are not. Since most of the decrement develops during the first minute for the work curves in this study, it is evident that the shortest set is the most efficient in spite of the lower initial level. The total amount of addition done under the respective conditions, during one minute, is 51.5 examples for Condition I, 49.5 examples for Condition II, 47.6 examples for Condition III, and 49.3 examples for Condition IV. In percentages, Condition III is 10 percent less efficient than Condition I. Graph 1 expresses graphically the results shown in Table I.

TABLE I

A COMPARISON OF THE INITIAL LEVELS AND DECREMENTS UNDER THE FOUR CONDITIONS

Condition	First Q.M.	Second Q.M.	Decrement	Third Q.M.	Fourth Q.M.
I	15.3±.5	12.9±.4	2.4	11.4	11.9
II	15.3±.5	12.4±.3	2.9	11.1	10.8
III	15.4±.5	10.9±.4	4.5	10.6	10.7
IV	15.9±.5	11.0±.5	4.9	11.2	11.2



GRAPH I

Experiment I; Part B. It seemed best to repeat the experiment just described on a larger group of subjects, in

order to be sure of the reality of the phenomenon of concomitance between set and decrement, and if possible to get clearer results on initial level. This time forty subjects were used, working en masse in a large auditorium. They were divided as before into four groups of ten each. Each group went through all four conditions, on separate days, but every group went through the conditions in a different order.

The results are much more clean-cut than before, possibly due to the superior working conditions. A glance at Table II shows in general both larger differences and smaller probable errors.

Influence of quantitative set on initial level. There is a clear tendency for the initial level to vary directly with the set. Condition I gives an initial level of 13.6 examples per Q.M., Condition II gives 13.8, Condition III gives 14.7, and Condition IV gives 15.3. Between these levels, some of the differences are statistically significant and others not; but the consistency of the trend, taken in the light of later results, makes the genuineness of the phenomenon extremely probable.

Influence of quantitative set on decrement. Upon this question, the results of this second study amply corroborate those of the preceding. There is a definite tendency for the decrement to vary directly with the quantitative set. Condition I gives a decrement of 2.6 examples, Condition II gives 3.8, Condition III gives 4.4, and Condition IV gives 5.1.

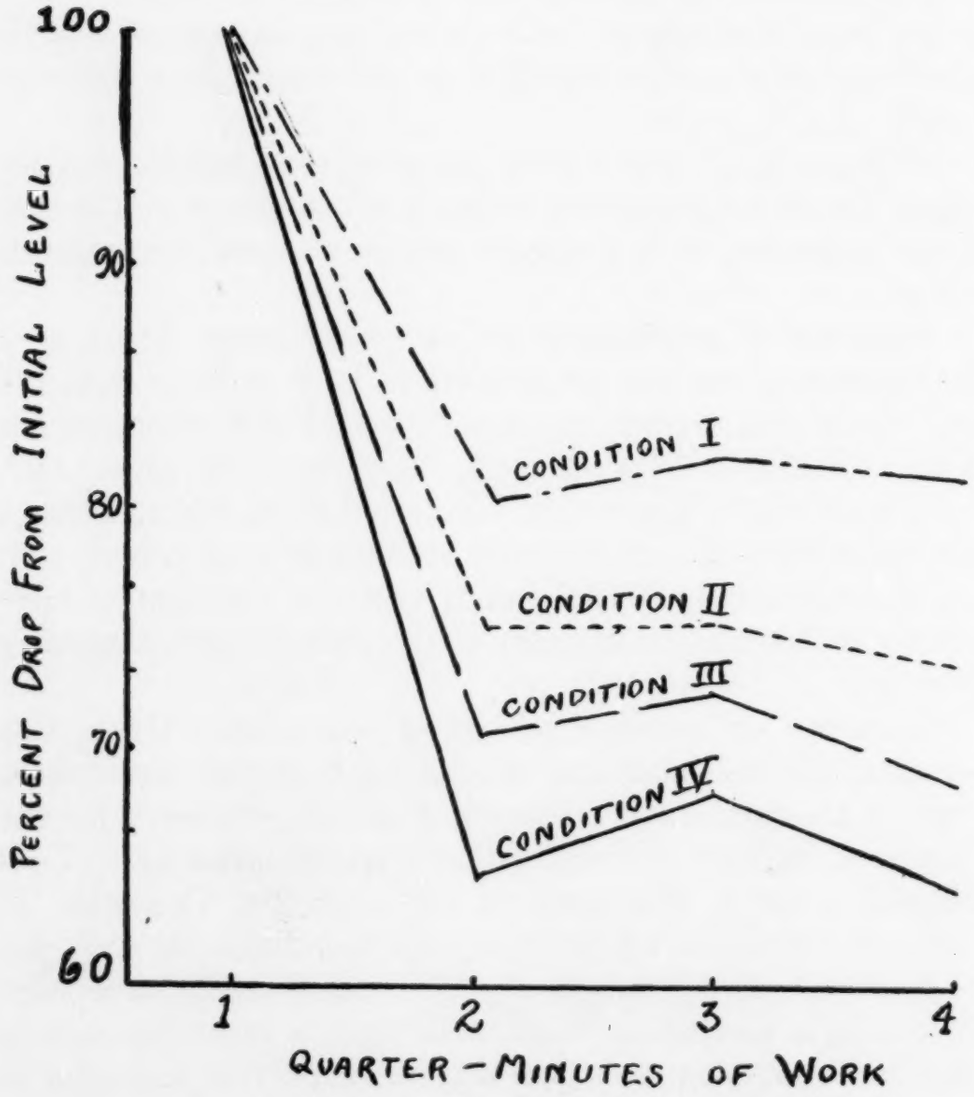
In Graph 2, the curves of this second study have been plotted on a percentage basis, as if from a common starting point at 100 percent. The regularity of the variation is surprising. And the difference between the levels tends to increase later in the curves.

TABLE II

INITIAL LEVELS AND DECREMENTS UNDER THE FOUR CONDITIONS

Condition	First Q.M.	Second Q.M.	Decrement	Third Q.M.	Fourth Q.M.
I	13.6±.34	10.7±.26	2.9	11.0	10.8
II	13.8±.32	10.0±.29	3.8	10.2	9.8
III	14.7±.35	10.3±.28	4.4	10.8	10.0
IV	15.3±.34	10.2±.32	5.1	10.9	10.2

Experiment II. In the previous experiment, as was indicated, the quantitative set was a combination of *time* and *amount.* It was not demonstrated whether both or only one of them produced the results. Therefore, to settle this



GRAPH 2

question, a second experiment was instituted in which amount set was varied independently, and later time set was independently tried.

This second experiment was performed at the University of Chicago, during the summer of 1927. Twenty-four subjects, all graduate students of considerable training in psy-

chology, took part. They worked in pairs, acting alternately as subject and experimenter. The work was done in separate rooms.

A preliminary practice period of two weeks was completed, in which every subject went twice through all of the conditions of the experiment. After that, the four cycles of the regular experiment were run, a week being taken for one cycle. No two conditions were used on the same day.

A cycle consisted of going through all four conditions once. The first two cycles of the main experiment were on *amount* set, the last two on *time* set. Hence time set had the advantage of practice, and no comparison between the absolute levels of efficiency under the two conditions is justified. The author plans a further experiment in which two independent groups will be started at the same time, one on the amount set and the other on the time, to determine which gives the highest absolute level.

The conditions of the present experiment follow.

'Amount' Set. Under the amount set the subjects were given a definite number of lines of pairs of digits to do and instructed to keep working till they completed them, working at all times as fast as they could with accuracy. No time was mentioned. Four conditions were used; Condition I, in which they were presented with three lines of work to do; Condition II, with six lines; Condition III, with twelve lines; and Condition IV, with twenty-four lines.

'Time' Set. Under the time set, the subjects were always given an equal amount of work to do, an entire page, which was enough to keep them busy even under the longest time employed. Hence amount was not a factor in any condition. The time set was given by telling the subjects they would be stopped at the end of a certain definite number of minutes. They were to work as fast as possible with accuracy, but no definite amount was to be done. Four conditions were used; In Condition I, they were told to work two minutes; in Condition II, four minutes; in Condition III, eight minutes; and in Condition IV, sixteen minutes.

In every case, a signal was given each quarter-minute,

and the subject made a check opposite the example he was on, so that work curves could be plotted later by quarter-minutes.

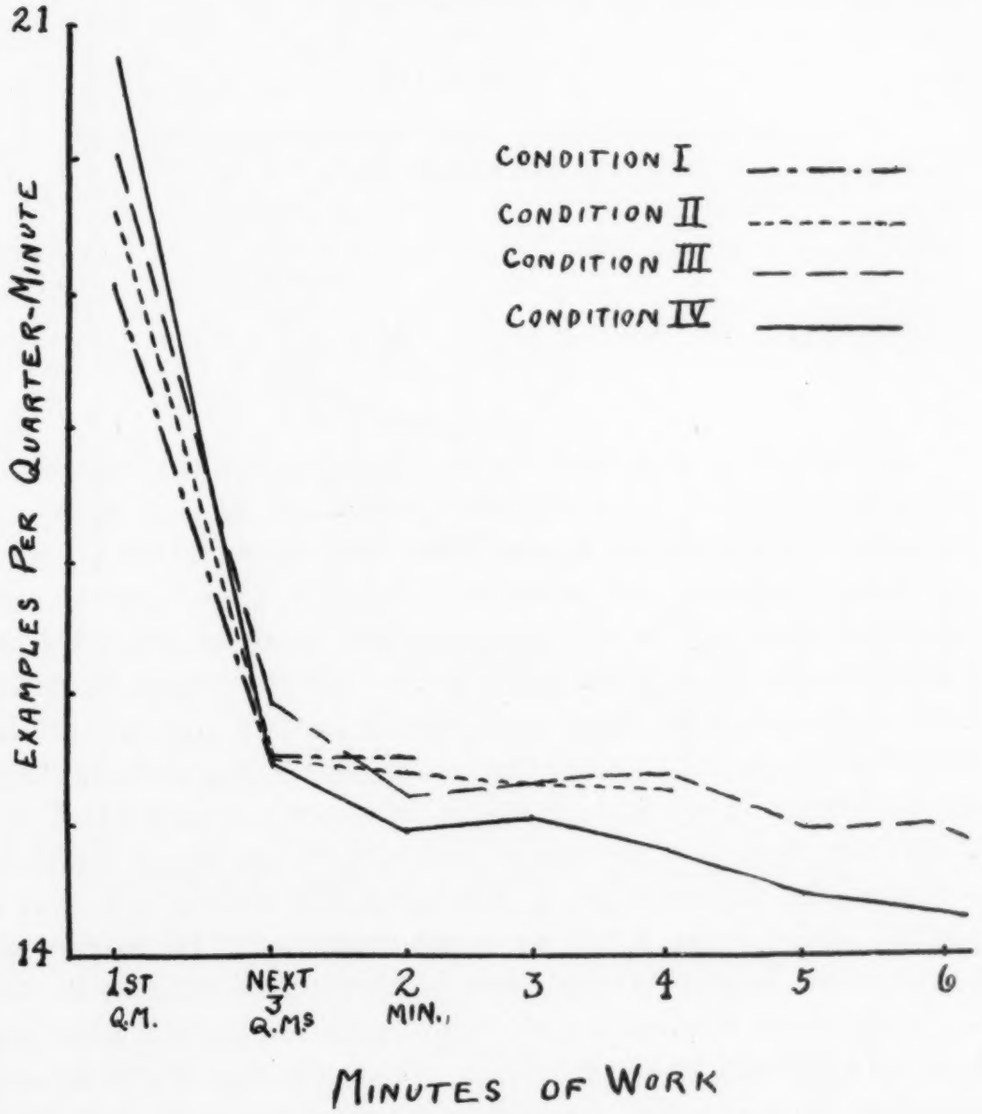
In order to eliminate practice effect, in addition to the two-week practice series, we employed the method of counter-balanced order in the main experiment. A fourth of the subjects began on Condition I, another fourth on Condition II, etc. In the second and fourth cycles the order was reversed. The results show that practice had not entirely disappeared by the end of the practice series, but had fallen to a negligible amount. For, whereas the average gain during the practice period was six examples per Q.M., there was only a gain of three during all the rest of the experiment.

Results

The results of the two sets are presented separately. In general, it may be said that the results for the amount set alone corroborate those of the previous experiment on *time-amount* set combined. Moreover, they are more clear-cut than the previous results. On the other hand, the results for time set alone do not show any definite tendency, the variations being of a chance order. This seems to demonstrate the point that it is the amount set and not the time set which is influential in determining the initial level and decrement, and that time set alone is without definite influence on the work curve. Where time-amount set is used, it is the amount aspect of it, rather than the time aspect, which is operative.

'Amount' Set. *A. Initial level.* In Table III are presented the average results for the first quarter-minute's work, under each condition. The results are averages of the two cycles, since no material difference appeared between the cycles. Condition I, the 3-line condition, gives 19.2 examples per Q.M. as an initial level. Condition II (6 lines) gives 19.5 examples, Condition III (12 lines) gives 20.0, and Condition IV (24 lines) gives 20.6. Between the first and fourth conditions there is a difference of 1.4 examples per Q.M., or a gain of about $7\frac{1}{2}$ percent for the longest set over the shortest

set. That this difference is statistically significant is shown by the fact that the P.E. of the difference is .38. But of much more significance is the fact that this same direct relationship between amount set and initial level has been



GRAPH 3

demonstrated in three separate experiments, with different subjects each time. It can therefore be stated with considerable assurance that under conditions comparable to those here used, *the initial level of the work curves will vary directly as the amount of work with which the subject is faced at the start.* Graph 3 shows the relation graphically.

B. Decrement. Referring again to Table III, column 3, the drop from initial level is shown for each condition. For Condition I, it is 3.5 examples per Q.M. decrement; for Condition II, 3.8 examples; for Condition III, 4.1 examples; and for Condition IV, 4.9 examples.

TABLE III

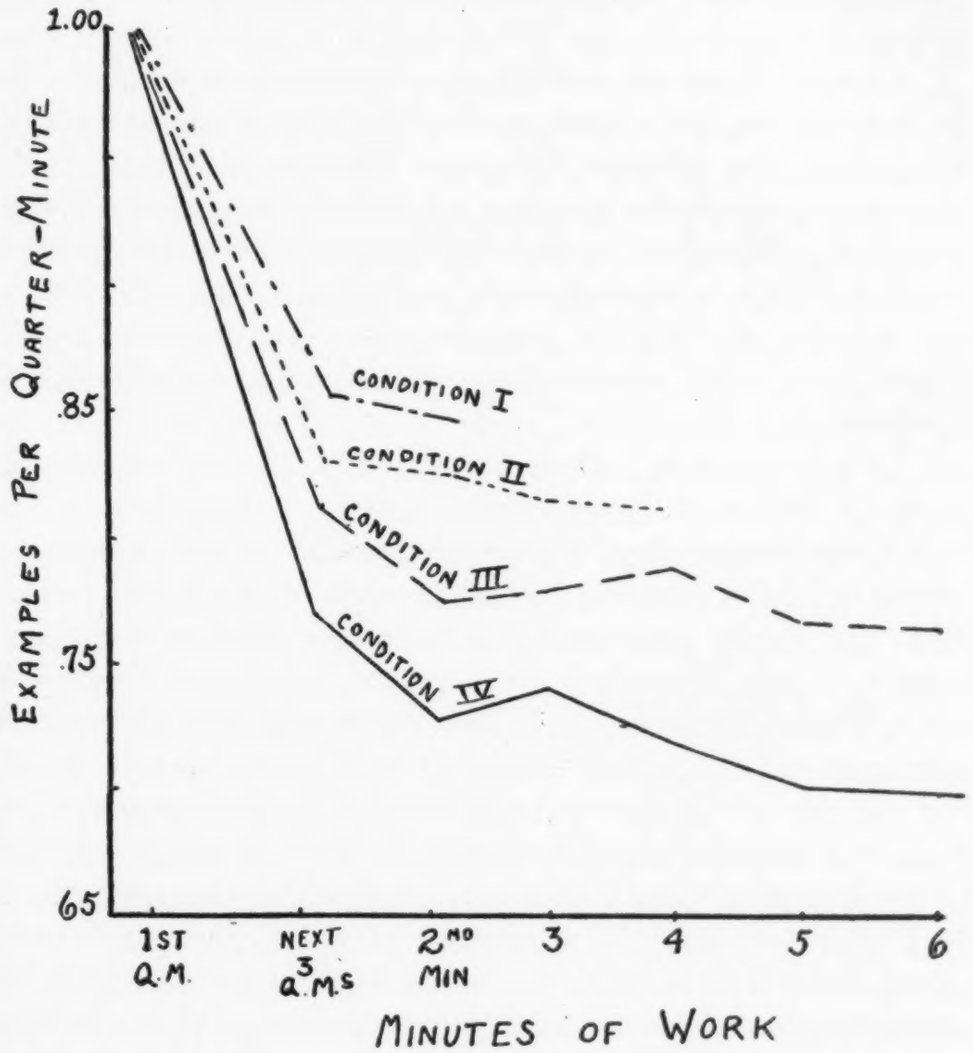
A COMPARISON OF THE INITIAL LEVELS AND DECREMENTS UNDER THE FOUR CONDITIONS

Condition	First Q.M.	Next Three Q.M.'s Averaged	Decrement
I	19.2	15.7	3.5
II	19.5	15.7	3.8
III	20.0	15.9	4.1
IV	20.6	15.7	4.9

In Graph 4, the work curves for the various conditions have been plotted on a percentage basis so that they would all start at the same point; and they have been carried through as many minutes as possible. Beyond these points the curves would not be reliable, because some of the subjects had finished. It will be noticed that the difference in initial level in favor of the long condition is lost by the end of the first minute, and thereafter there is an increasing disadvantage in the longer sets. It is possible, of course, that part of the difference in decrement under the two unlike sets is a direct result of the different initial levels, on the assumption that a higher initial level must be compensated for by a greater subsequent drop. At any rate, in this experiment as in the first, the short condition is shown to give the highest absolute level of efficiency in the long run. The general statement can therefore be made that, under similar conditions, *the decrement or drop from initial level will vary directly as the amount of work with which the subject is faced at the start.*

'Time' Set. *A. Initial level.* Contrary to the clear-cut relation demonstrated between initial level and amount set, no definite relation appears when time set is used alone. The initial levels under the respective time sets were as follows; Condition I gave 23.6, Condition II gave 23.0,

Condition III, 23.0 and Condition IV, 23.4. The greatest difference between any two conditions was only six-tenths of an example. We are forced to conclude that the results in



GRAPH 4

Experiment I, where a combination time-amount set was used, are attributable to the amount aspect of the quantitative set, and not to the time aspect. Under these conditions, then, *time set does not influence the initial level of the work curves.*

B. Decrement. Here, again, there is no such relation demonstrated between time set and decrement as was shown between amount set and decrement. The respective decre-

ments under the various conditions, beginning with Condition I, were 5.1, 4.8, 5.0, and 4.9. No definite trend of any kind is shown. The largest difference in decrement between any two conditions is only three-tenths of an example.

There is, however, one extremely important result. The decrements under the time set are about equal for all the four conditions, the average being 5. This is the level of the decrement under the amount set for the longest condition, Condition IV. But, under the amount set, the shortest condition gave a decrement of only 3.5. Evidently, then, the amount set operated to decrease the decrement considerably for the shorter sets, rather than lengthening it for the longer sets.

We may therefore draw the following *general conclusions* from the results of Experiments I and II.

1. The initial level of efficiency with which a subject works will be a function of the amount of work with which he is faced, the greater the amount the higher the initial level.

2. The decrement, or drop from the initial level of efficiency will also be a function of the amount of work, and the greater the amount the steeper the decrement.

3. Neither the initial level nor the decrement are affected by the length of time that a subject is told he is to work.

Experiment III. If, as the results of the previous experiments demonstrate, a short task establishes a set which is conducive to a higher level of performance than that resulting from the set established by a long task, the following question is raised; Could an individual split up a long task into a series of short tasks, and, by presenting them one at a time, induce his subjects to accomplish an equivalent amount of work in less time? If an individual faced with a one-minute task attains a higher level of efficiency during that one minute than an individual who is faced with a five-minute task does during the first minute, then if the five-minute task could somehow be presented to the subject as five one-minute tasks we should expect his level of efficiency to be

higher than when it is presented as a single five-minute task.

It is obvious that, if this question were to be given a fair test, the continuity of the work should not be interfered with, because then it would not be the set which operated to raise the level of efficiency, but the rests which the subject got between minutes. Hence the five-minute task must be broken up in some way which does not interfere with the actual continuity of labor, so that the short set is imparted to the subject, and yet no rest introduced between minutes.

To fulfil these conditions, the following plan was devised. To give a clear-cut break, which the subject would feel as a break in the task at the end of every minute, the same material was pasted on two sides of a sheet of cardboard, and the subject was told to turn over and start working on the opposite side every time a signal was given. Such a signal was given every minute. The mere fact of turning over served to furnish a distinct break in the task, and yet took no appreciable time, and hence gave the subject no rest-period. Against this broken or short-set condition, was set a continuous or 'long-set' condition, in which the subject worked continuously for the entire ten minutes on one side of the sheet of cardboard.

In order to see how the effect of such a short-set or broken arrangement would compare, as to its amount of saving over the long-set condition, with an actual change of task, such as Chapman used, we also employed a third condition, namely, a 'changed-task' condition, in which the subjects worked on cancellation in the alternate minutes, when they turned the card over.

The experiment therefore employed three distinct conditions of work, as follows:

Condition I, Continuous addition of pairs of digits on one side of card, for ten minutes.

Condition II, Alternation every minute between addition on one side and addition on the other side of the card, for ten minutes total time.

Condition III, Alternation every minute between addition

on one side and cancellation of numbers on the other side of the card, for ten minutes total time.

The three conditions will be referred to, hereafter, as the *continuous*, the *broken*, and the *changed-task* conditions, respectively.

Three cycles of the experiment were completed, and counterbalanced order was employed throughout to eliminate practice effect.

Fifteen subjects, all graduate students in the Chicago Laboratory, were used, and they acted in pairs, serving alternately as subject and experimenter.

Results

In Table IV, are shown the average number of additions per quarter-minute for each of the three conditions. This shows the difference in absolute level of efficiency under the different sets. In the first and second cycles the tendency is alike, *i.e.* toward a higher level for the broken-condition than for the continuous, and a still higher level for the changed-task. Since the changed-task condition also had the advantage of the broken-set, we can estimate the relative amount of effect of a broken-set alone versus a change-of-task alone by comparing the net gain of the broken over the continuous set with the net gain of the changed over the broken set. The results tend to show that they have nearly an equal influence. In other words, a person gains nearly as much on the average from having a continuous task broken up into small units as from a frequent change of task.

Table IV

Absolute level of efficiency under the three conditions (examples done per quarter-minute)

Condition	Cycle I	Cycle II	Cycle III	
			Includ. 1st Min.	Without 1st Min.
I. Continuous.....	8.9±.06	11.3±.06	13.4	13.3
II. Broken.....	9.4±.07	11.8±.08	13.0	13.4
III. Changed.....	10.1	12.4	13.8	13.8

An apparent reversal appears in Cycle III. This disappears when the first minute is omitted from the average

of the ten minutes. But still the difference between Conditions I and II in this cycle is so small as hardly to be significant. This is probably explained by the fact that, as the subject gets more used to the experiment, the set ceases to operate because he realizes that just as much work is involved in either case. The differences between the averages for the continuous and broken conditions in Cycles I and II are significant statistically. In Cycle III they are not. But neither is the difference in this cycle between the continuous and changed-task conditions as marked as in the former cycles. All the measures are much nearer together. It appears either that the task had become so automatized that neither set nor change of task materially affected the level; or, as is more likely, the subjects had come to realize that an equal amount of work was involved under all conditions, and hence the set had ceased to operate to any extent.

The conclusion may therefore be drawn from this third experiment that, *where a long task is broken up, as regards the subject's set, into a series of short tasks, it will be performed at a higher absolute level of efficiency than when presented as a whole at the beginning, even though in both cases the subject works continuously without respite.* The amount of gain will be nearly as great as the gain resulting from such a frequent change of task, as Chapman reported.

General Conclusions

On the basis of the results already presented separately for the three experiments, the following conclusions may be drawn.

I. The height of the initial level of efficiency in a task of the type used in this experiment is directly proportional to the subject's quantitative set; but only when the quantitative set is an *amount* set, not a *time* set.

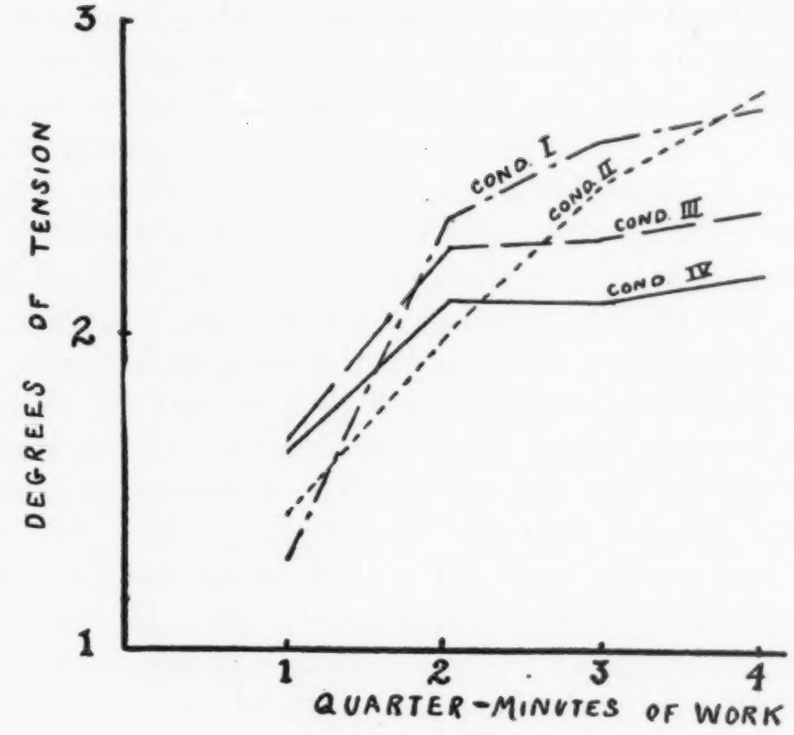
II. The steepness of the decrement which will develop in a given amount of time, in such a task, is directly proportional to the subject's quantitative set; but only when the quantitative set is an *amount* set, not a *time* set.

III. If a long task is presented to a subject in parts, even though the subject work continuously, with no respite between parts, he will work at a higher level of efficiency than he will when he regards the task as presented as a whole.

Interpretation of Results in Terms of Tension

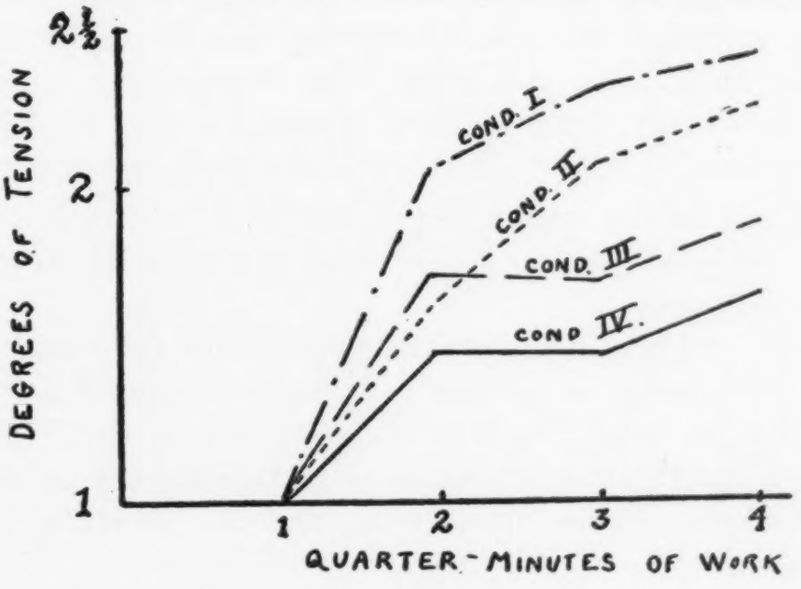
It is possible that there is some relation between 'set' as a mental attitude determining the level of efficiency and 'set' as a condition of muscular preparation. A study of the amount of muscular tension under which the subject is working, under different quantitative sets, as correlated with the particular mental set might throw some light upon the relation. The arrangement for studying the amount of muscular tension under which the subject is working at any given moment is described at the beginning of this article, but will be briefly repeated here.

As shown by Morgan and others, when a subject is working at increased tension, he tends to press harder with the reacting member of the body. If the subject is writing, he will press harder on the pencil. In the present experiment, therefore, which involved writing down answers to simple additions, the strength of pressure exerted on the pencil was recorded by placing five sheets of thin paper, alternated with carbon paper, underneath the sheet on which the subject was writing, and fastening the whole to a stiff sheet of cardboard. The amount of pressure could then be determined by two criteria; (a) the number of carbon sheets through which the impression took, and (b) the clearness or legibility of the last carbon copy showing any impression. The first of these criteria is more objective than the last. Hence each subject's work was rated as to degree of tension at each quarter-minute, by two judges independently, on a basis of one to four degrees, in which 1 equals the least, and 4 the greatest degree of tension. These records were secured in Exper. I and II, but not in Exper. III. Entirely different judges were used in Expers. I and II. That it is not difficult to secure objectivity of results by the method here employed is proved by the fact that in both experiments the judges' ratings, both



GRAPH 5

(SAME AS ABOVE; PLOTTED FROM COMMON START)



GRAPH 6

by subjects and by quarter-minutes, correlated between .83 and .95, giving more correlations above than below .90.

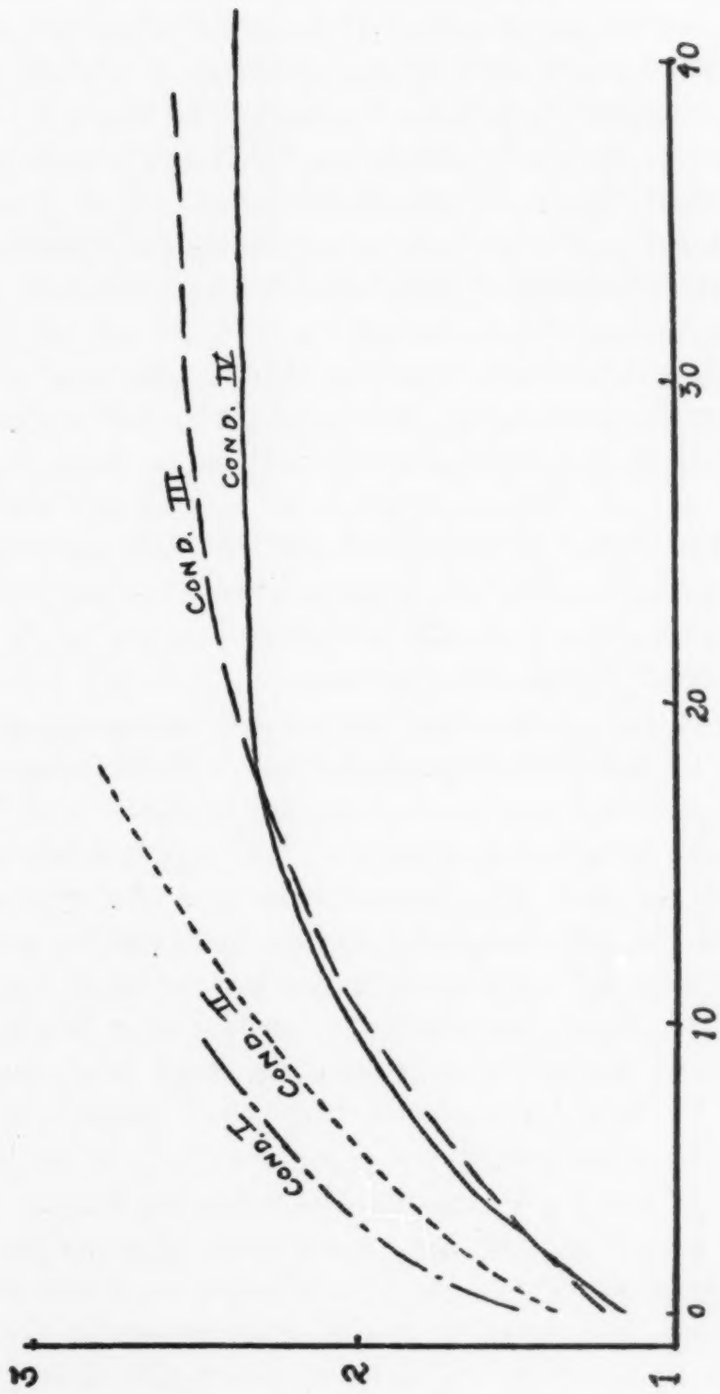
The judges rated the tension of each subject, under each condition, for each quarter-minute of work separately. This gave, when averaged for all the subjects, four average tension curves, by quarter-minutes, one curve for each condition.

For Exper. I. From Graphs 5 and 6, it is possible to determine the relation between the four work conditions as to (1) initial tension, and (2) the rise in tension during the first four quarter-minutes. It will be seen that the shortest condition has the lowest initial tension, but that it rapidly increases till by the end of the fourth quarter-minute it shows the greatest tension. Condition II has the next lowest initial tension and has a slightly smaller increment than Condition I; while Conditions III and IV have the highest initial level, but a correspondingly smaller increment, Condition IV having the least increment of all.

It is evident (1) that the level of initial tension is directly proportional to the quantitative set, the shortest set having the lowest initial level. (An exception to this is the fact that Conditions III and IV have the same initial level.) When we compare this result with the results of the first experiment of all as to the initial level of efficiency, we see that the two things tend to vary concomitantly. In other words, low level of initial efficiency in the short set is correlated with low initial tension in this condition, and high level of initial efficiency in the longer sets is correlated with a greater initial tension.

It is also evident from the tension results (2) that the steepness of increase in tension is inversely proportional to the quantitative set. There is no exception to this. The shortest set has the steepest increase in tension, the longest set has the least increase in tension, and the others are in proportion.

When we compare this fact with our initial experiment as to the relative decrement in efficiency for the several conditions, we discover that the two phenomena vary concomitantly. The shortest condition shows the least decrement in efficiency, and concomitantly the greatest increase



GRAPH 7

in tension. The longest condition shows the steepest decrement in efficiency and concomitantly shows the least increase in tension, and the others are in proportion.

The conclusion is obvious. The level of efficiency at any time is in part a function of the amount of tension under which the subject is working. Consequently where he exerts greater tension at the start, as in the longest *amount* set, he has a higher initial level of efficiency. And where he exerts less tension at the start, as in the shortest *amount* set, he has a correspondingly lower initial level of efficiency.

Of course, the mere fact that two things vary concomitantly is not sufficient proof of their causal relation, but it is presumptive evidence. The hypothesis with which we started, *i.e.* that the 'quantitative set' is, at least in part, a muscular set, involving degrees of tension or muscular readiness, has been given corroborative evidence by our results. Previous published experiments of the author tend to demonstrate increased efficiency in mental work as a result of increase in muscular tension.

For Exper. II. The same means for measuring tension was used as in the preceding experiment. Two judges independently estimated the tension of each subject under each work condition by quarter-minutes. Their judgments correlate between .80 and .95. In order to plot the curves, the judgments of the two judges were averaged, and an average curve of tension by quarter-minutes was plotted for each condition, and then smoothed by inspection. Instead of merely plotting the curves through the first four quarter-minutes, as in Graphs 5 and 6, they were plotted to the very end of the work period.

A study of Graph 7 brings out the following facts.

I. Just as in the previous experiment, the steepness of rise in the tension curves is inversely proportional to the quantitative set, the shorter set giving the steepest rise, and the others in proportion. This agrees with the theory that increased tension in the shorter sets compensates for fatigue and cuts down the steepness of the decrement, whereas in the longer sets there is not so great an increase in tension and hence a steeper decrement.

II. Moreover, the longer the quantitative set the longer does it take for the tension curve to reach its maximal height. This is in agreement with the results of Exper. I, where the maximal tension was reached in Condition II by the end of the 6th Q.M., in Condition III by the end of the 10th, and in Condition IV by the 18th. In Exper. II the highest part of the curve in the longest condition does not come until the end of the work period, though a virtual asymptote is reached at the end of the 30th Q.M.

III. But contrary to our previous results, the initial level of pressure is not directly proportional to the quantitative set, but inversely proportional. It is difficult to say how this relation should be interpreted; but it casts doubt on the direct relation between initial level of efficiency and tension.

Conclusions Regarding Tension

It is evident from the results of the two tension experiments that a very close relationship exists between the particular quantitative set under which an individual is operating and the degree of increased tension which he will manifest. It seems reasonable to conclude that the quantitative set is, in part at least, a muscular set, analogous to that of the subject who is preparing to lift a heavy or light weight. In the case of the quantitative set, however, the tendency seems to be toward a lesser increase of tension for the long task, an attempt to strike a pace which can be kept up for a longer time; and toward a greater increase in tension for the short task in anticipation of the nearness of the end of work.

The close relation between tension and the phenomenon of initial spurt is worth mentioning. Initial spurt consists of a high initial point of efficiency followed by a rapid drop to a much lower level. Its limits are somewhat comparable also to those of the initial spurt. The subject merits investigation as a possible way of throwing light on the obscure phenomenon of initial spurt which is a very real thing and yet has until now received no adequate explanation.

(Manuscript received December 3, 1928)

ANOMALIES OF PERIPHERAL VISUAL ACUITY

BY ELLIS FREEMAN

Psychological Laboratories, Cornell University

The Measurement of Peripheral Acuity by the Translation Method [1]

The periphery of the retina exhibits an astonishing incompleteness of correspondence between the visual experiences which are associated with it and the physical factors upon which these experiences are based.[2] This incompleteness of correspondence is of the utmost theoretical value to the problem of the nature of perception in general, and is important to any school of psychology although it is most akin to the type of data upon which the doctrine of *Gestalt* depends for its arguments. It is the purpose of this paper to bring together the older experimental work on peripheral acuity, and also certain new material which has a direct bearing, first, on the special problems of the periphery, and, secondly, on the more general problems of perception at large. It is also proposed to emphasize the anomalies which these works reveal, namely the absence or incompleteness of correspondence between the experiences and their physical determinants, without, however, attempting to produce a synthesizing principle of explanation. Such an explanation is, in the

[1] By *acuity* is here meant the capacity for discriminating the parts of a complex, as in the perception of a letter of the alphabet, or the distinguishing of individual dots and other figures.

[2] The term *physical factors* of vision here means the combination of stimulus and dioptrical system of the eye upon which the final retinal image depends. Or, put in another way, it may mean everything other than the psychological experience itself; namely, stimulus, refractive action of lens and of aqueous and vitreous humors, changes in illumination due to the pupil. The behavior of the retinal receptors, optic nerve tract, and terminal brain cells could be properly included under the term, but is omitted because the influence of these mechanisms is a separate problem of which almost nothing is known and with which this paper is not concerned. Here we shall consider, on the one hand, all that goes toward producing the retinal image, *i.e.* the physical factors, and, on the other, the psychological experience which accompanies it.

present state of knowledge, worth very little and even dangerous and misleading, as will appear in the citation of the works of several venturesome theorists. The only safe course warranted by the facts at our command is the recording of a complete description of the phenomena, which some subsequent broad view of perception may be able to reconcile and to incorporate.

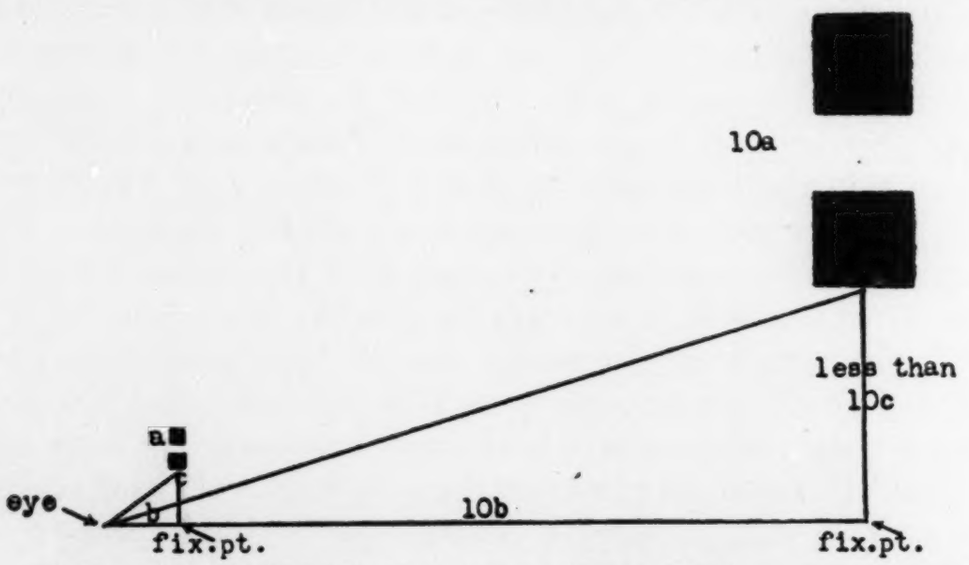
As far as the literature shows, the existence of anomalies in connection with the periphery of the retina was unsuspected until the discovery of the Aubert-Foerster phenomenon.[3] Aubert, alternating with Foerster as observer, compared peripheral visual acuity when small figures and letters were seen at a short distance, with acuity when large figures and letters were seen at a correspondingly greater distance. The experimental conditions were such that the retinal image of the large and small figures was the same in size. Also the illumination reaching the cornea was in both cases the same. Yet, with all external conditions thus regulated that the ultimate retinal image was in both cases necessarily the same and should, therefore, have elicited the same degree of visual acuity, a striking and apparently unaccountable higher degree of acuity was discovered in connection with the small figures at a short distance than with the large at a correspondingly greater distance.

In other words, here lay an inexplicable incongruity with the accepted inferences of purely geometrical optics, that if an object were of size *a*, the eye of the observer at distance *b* from the fixation point on the campimeter, and the distance one the campimeter between fixation point and object were *c*, then a similar object of size *10a*, for example, with the observer's eye *10b* from the fixation point, would necessarily have to be resolved with equal clearness and ease at a distance of *10c* from the fixation point on the campimeter.[4] As a matter of fact, Aubert found this last dimension of the large constellation, namely distance between object and fixation point, much less than strict geometrical proportionality demanded. Therein lay the

[3] H. Aubert, Physiologie der Netzhaut, Breslau, 1865, 235–253.

[4] It goes without saying that in the case of both constellations the same retinal meridian is being tested.

incongruity which constitutes the Aubert-Foerster (A-F) phenomenon.[5] Although everything external was arranged to produce a retinal image of the same size, intensity and position in both cases, the result in experience was that the large figure suffered a reduction in clarity and elicited a lower degree of acuity of peripheral vision. Or, to express the phenomenon in other terms, the large figure, despite the fact that it was designed to give a retinal image precisely identical



For the sake of intelligibility the squares are shown in full view. But they are to be taken as standing in profile, so that here only a line representing one edge should appear.

FIG. 1

with that of the small figure, could not be resolved so far eccentrically on the campimeter (and therefore on the retina) as the small, but had to be brought much nearer to the fixation point (and therefore to the fovea). Fig. 1 graphically represents the phenomenon.

In the discovery of the A-F, Aubert employed principally[6] two small black squares which he called the objects of the small constellation, separated by a spatial interval equal to the side of one of the squares. He determined the position on the

[5] For the sake of convenience, the Aubert-Foerster phenomenon will henceforth in this paper be called the A-F.

[6] With the method remaining the same, he also employed rows of letters and numerals. The procedure was to determine how many of these in a given row could be recognized in each constellation, and then to compare results for the large and for the small. Here again was revealed a pronounced A-F as in the case of the black squares.

campimeter—and consequently on the retina—where the squares ceased to appear as resolved into two separate figures. With the size of the squares and their interval increased several fold, and the distance of the observer's eye from the fixation point correspondingly increased, he now determined the position on the campimeter at which the resolution for the large constellation ceased in the same way. The resulting decrease in eccentricity for the large appeared with the utmost regularity in every experiment, and, as already noted, constituted the A-F. Dominated purely by the attitude of the physicist, Aubert sought no explanation other than one based upon physical determinants. Without going further into the matter, he was content with the very vague suggestion that the cause of the phenomenon was physiological and lay principally in the retina and partly in the lens. In his opinion, with the lens accommodated to a more distant fixation there occurred a "translation of the rod-stratum, which reduced the penetrability of the light rays." [7] This means very little and explains even less.

Heinrich,[8] accepting the A-F as a fundamental fact of peripheral vision, also proceeded to give a physiological explanation, but sequentially and fully developed as Aubert's was not. He made the lens and its accommodation exclusively responsible, asserting that in order for a peripherally observed object to attain its greatest clearness as an image on the retina, the lens must flatten out peripherally where the ray from the object strikes it. (In direct vision, on the contrary, once the lens is accommodated for the fovea it serves without further modification of any part.) Consequently, when the lens is quite thick, as during near accommodation (for the small constellation), the peripheral parts of the lens are sufficiently bulky to allow the additional amount of thinning out which is necessary to give the peripheral retinal image its greatest clearness. But when the lens is already very thin, as during distant accommodation (for the large constellation), the peripheral parts of the lens possess too little bulk to begin with to permit the additional amount of necessary thinning out. Thereupon, when distant accommodation obtains and the lens is already thin, the eccentricity of the large constellation must be so far reduced as to correspond with the amount of peripheral flattening out of which the lens is still capable. In this wise, according to Heinrich, arises the geometrical incongruity which constitutes the A-F.

Jaensch,[9] undertaking an experimental study of the problem, was the first to whom it occurred that the A-F might be independent of the dioptrical apparatus of the eye, and otherwise conditioned. That it is independent, he very clearly demonstrated. He examined the acuity of peripheral vision in its relationship to the more general and more fundamental problems of the nature of perception. And it is his very important contribution that he in a large measure liberated the treatment of the retinal periphery from the purely anatomical-physiological point of view.

Jaensch conceived visual perception as a function involving the whole organism, demonstrating that it did not suffice to know the physical factors which govern the production of the ultimate retinal image, at any rate in the case of acuity in the

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[7] Aubert's words are: ". . . bei der Akkommodation auf grössere Entfernung, eine Verschiebung der Stäbchenschicht stattfände, welche die Durchdringlichkeit der Lichtstrahlen verringerte."

[8] W. Heinrich, Die Aufmerksamkeit und die Funktion der Sinnesorgane, *Zsch. f. Psychol.*, 1896, 9, 342–388; 11, 410–431.

[9] E. R. Jaensch, Zur Analyse der Gesichtswahrnehmungen, *Zsch. f. Psychol.* Ergzbd. 4, 1909.

periphery. He conducted a series of experiments designed to determine the exact rôle of each of the three physical factors which might possibly be the cause of the A-F. These are crystalline lens, pupil, and retina. He succeeded, in the opinion of the present writer, in completely eliminating these as determining and immediate causes. His point of departure is the following consideration: (1) In regard to the influence of the lens, if the A-F persists in appearing even when accommodation is, by whatever means, kept the same for the small and the large constellation, then Heinrich's explanation is untenable. For Heinrich bases his reasoning upon changes in accommodation and upon a characteristic disability of the lens to thin out a bit more at the periphery when already thinned out in accommodation for the distant fixation point. But if the lens is kept constant for both, as Jaensch proposes, then it cannot be held that the small constellation has enjoyed the advantage of a capacity for further thinning out (at the periphery) which accompanies the greater thickness of the lens. (2) In regard to the influence of the pupil, if the A-F is revealed under the preceding conditions, then changes in the pupil can have no effect either, because with accommodation and illumination constant for both constellations, the size of the pupil necessarily remains the same in both cases, since the pupil varies with accommodation and illumination. Therefore the A-F cannot be attributed to pupil changes when there are none. (3) In regard to the influence of the retina, upon which Aubert insisted, if the A-F appears under the above conditions, then the retina cannot be the cause, since, as the ultimate image which it receives in both cases is identical, it would necessarily be obliged to deal with them both in the same manner, presumably behaving alike toward like images.

The force of this logic, based upon the true inwardness of the known relationships between all the conceivable physical factors, is coercive and commends itself to acceptance. It only remained, therefore, for Jaensch to show that the A-F continues to appear, even with constant thickness of the lens, in order to demonstrate that the A-F is not determined by mere changes in the anatomical and physiological relationships of the dioptrical apparatus.

This demonstration he has successfully made by the following method. In order to obtain the essential condition of the same accommodation for both constellations, he employed for the small a convex glass lens of 1.75 D placed directly before the observer's eye.[10] For the large the bare eye alone was used. Thus, in the case of the small near constellation the crystalline lens was kept, artificially to be sure, as thin as it was naturally in the case of the large distant constellation. Otherwise Jaensch's method was identical with that of Aubert. Under these conditions of identical lens thickness in both cases, the same decided A-F reappeared. This was sufficient direct demonstration that the variations in the crystalline played no part, and inferentially that the pupil and retinal conditions played none either, in the creation of the A-F. Now that all physical factors had remained the same in both cases and the A-F still occurred, any argument based upon changes in the dioptrical apparatus of the eye was untenable.[11]

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[10] The manner of determining the precise power of the glass lens needed was simply a matter of ophthalmological routine. Jaensch goes into it fully. *Op. cit.*, pp. 19–26.

[11] So far it seems perfectly safe to go with Jaensch, *i.e.* physiological-anatomical relationships cannot be used to explain the A-F. But very serious difficulties arise when we try to follow his own explanation on the basis of a "central" or "psychological" factor, which he calls attention and construes in an especially unacceptable

Similarly Kaila [12] found the presence of the A-F in experiments with the haploscope, where differences in accommodation were also eliminated.

Jacobsson,[13] examining foveal acuity with constellations of different sizes and at corresponding distances which produced identical ultimate images on the retina, dealt with the influence of apparent magnitude. Incidentally he discovered a situation in foveal vision corresponding to the A-F, but much less pronounced.

Henning [14] also recognized a foveal A-F. The conditions of his observations are so loose and uncontrolled that they do not admit of an experimental check. Furthermore, he makes a demand on credulity which it is, one must confess, very hard to satisfy. He asks the reader to accept reports from observers of details, like minute twigs on the branches of trees, which are seen from the Strassburg astronomical observatory, with the bare eye, on the ridge of the Vosges Mountains 50 kilometers (sic) distant.

In the work of Jaensch and Schönheinz [15] is treated the question of whether the addition of details to that part of the campimetric field between fixation point and figures to be resolved increases or decreases the amount of the A-F. Their conclusion is that as the number of details in this intervening area increases, the A-F tends to decrease, even though all other conditions remain as in the earlier work of Aubert and of Jaensch himself.

A similar tendency toward a reduction of the A-F has been found when details, like a black band are added, not in the intervening area between fixation point and figures but in the field beyond (more peripheral than) the figures themselves.[16]

Kreiker,[17] on the strength of refined reflections which are, however, vitiated by the coarseness of the experimental work upon which they are founded, contends that no condition such as the A-F properly exists. The results which presumably demonstrate it are, as he argues, due to the unconscious employment by the observer of one criterion of clearness for the small constellation and another for the large. By the use of a method of "double control," which not only permits the observer to make a report but enables the experimenter to check its correctness, the A-F, according to Kreiker, appears neither in the periphery nor the fovea.

Dobrowolsky and Gaine [18] also found no A-F in the periphery. But it is only

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manner. The question of the satisfactoriness of his attention factor as a basis of explanation, which is a separate problem in itself, is treated fully and experimentally in E. Freeman, Untersuchungen über das indirekte Sehen, *Zsch. f. Psychol.*, 1929. For the present the problem of explanation of the A-F, whether Jaensch's or any other, need not be gone into here, because the primary concern of this paper is only with the objective outcome of Jaensch's data.

[12] E. Kaila, Eine neue Theorie des Aubert-Foersterschen Phänomens, *Zsch. f. Psychol.*, 1921, 86, 193–235.

[13] M. Jacobsson, Ueber die Erkennbarkeit optischer Figuren, usw, *Zsch. f. Psychol.*, 1916, 77, 1–91.

[14] H. Henning, Die besondern Funktionen der roten Strahlen, usw, *Zsch. f. Sinnesphysiol.*, 1919, 50, 275–310.

[15] E. R. Jaensch & Wilhelmine Schönheinz, Einige allgemeinere Fragen der Wahrnehmungslehre, *Arch. f. Psychol.*, 1924, 46, 3–60.

[16] E. Freeman, *op. cit.*

[17] A. Kreiker, Ueber das Aubert-Foerstersche Phänomen, *Graefes Arch. f. Ophthal.*, 1927, 118, 292 ff.

[18] Dobrowolsky & Gaine, Ueber die Sehschärfe an der Peripherie der Netzhaut, *Pflügers Arch. f. d. ges. Physiol.*, 1876, 12, 411–432.

fair to note that for the small constellation their observer was 50 cm from the fixation point, and for the large, which was correspondingly twice as big, he was at a distance of 100 cm. These dimensions represent a ratio of only 2 : 1, and at that only within the very narrow limits of one meter. Their results are, therefore, no refutation of the A-F as a product of defective experimental method, as they think, for within such narrow limits of absolute size a relationship of 2 : 1 is too small to reveal the phenomenon, and it should be said rather that their method was defective if they wished to produce the A-F for study. The relationship should be about 10 : 1, or perhaps more.

A summary of the facts of visual acuity in the periphery of the retina as demonstrated by the researches in the preceding account is as follows:

1. Large distant objects do not give rise to as high a degree of acuity as small, and correspondingly near, objects when the constellations stand in the geometrical relationship of about 10 : 1, although the retinal images are identical. This is the A-F as found repeatedly by Aubert, Jaensch, Kaila, and Jacobsson.

2. Large distant objects do give rise to just as high a degree of acuity as small, and correspondingly near, objects provided the geometrical relationship is small, as in the instance of 2 : 1, and the absolute dimensions involved are likewise small (within one meter) as in the work of Dobrowolsky and Gaine.

3. Large distant objects do give rise to just as high a degree of acuity as small, and correspondingly near, objects even with high ratios, as 10 : 1, if complicating details are added to the intervening field between fixation point and objects, or to the field beyond the objects, as in the work of Jaensch and Schönheinz and of Freeman.

Here, then, without going further, we have a curious set of apparent anomalies associated with the behavior of the retinal periphery. Always receiving an identical image on the retina, the observer in one case experiences a lower degree of acuity for the large constellation than for the small (when the relationship between the constellations is 10 : 1); in the other case the observer experiences an equal degree of acuity for both constellations when the relationship is small, as 2 : 1, or when the field contains complicating details in addition to the figures to be resolved.

The Measurement of Peripheral Acuity by the Splitting Method

It is noteworthy that in all the preceding researches on the acuity of peripheral vision the A-F is associated with one method of experiment, namely that of employing two figures (*e.g.* two black squares) at a fixed distance apart on a large white surface, which is made to recede from or to approach a stationary fixation point, thus carrying the figures with it further from, or nearer to, the line of regard. By this method the measure of acuity is directly the distance from the fixation point to the peripheral position at which the two adjacent figures just cease to be resolved as two distinct units and become fused into an undefined grayish area. The greater the distance at which this occurs from the fixation point the greater, therefore, the acuity. This method was employed by Aubert,[19] Aubert and Foerster,[20] Landolt and Ito,[21] Jaensch,[22] and others. For the sake of convenience it will here be called the *translation method*, for the two figures together with their constant interval of space between them are translated as a unit away from or toward the fixation point, while the position of the figures with reference to each other remains unchanged.

Another method of studying the acuity of peripheral vision is that which Guillery applied to foveal acuity.[23] It is also perfectly appropriate for the investigation of the periphery. The observer fixates a point at eye-level on the campimeter and the double objects which are to be peripherally resolved are, contrary to the translation method, presented at a given angle of eccentricity. One of the two objects remains stationary while the other, at first contiguous with the stationary one, is slowly and regularly shifted away from it

[19] H. Aubert, *op. cit.*, 219 ff.

[20] Aubert & Foerster, Beiträge zur Kenntnis des indirekten Sehens, *Graefes Arch. f. Ophthal.*, 1857, 3, Th 2, 1–38.

[21] Landolt & Ito, Die Untersuchungsmethoden, in *Graefe-Saemisches Handbuch der Augenheilkunde*, 2 Aufl., 1 Abt., 64 ff.

[22] E. R. Jaensch, *op. cit.*, 1–148.

[23] R. Guillery, Ueber die Empfindungskreise der Netzhaut, *Pflügers Arch. f. d. ges. Physiol.*, 1897, 68, 120 ff.

until the white interval has increased sufficiently to permit the two objects to be seen as separate, that is, to be resolved. By this method the peripheral acuity is inversely proportional to the width of the white interval needed to give the proper perception of separation between the two objects. Naturally, the less of white interval demanded for the resolution the greater the acuity. For convenience, this method will here be called the *splitting method*, for the two objects, first presented contiguously, are gradually split apart until the white interval has grown sufficiently large to produce the desired resolution.

Still another method, technically the most difficult, is possible. The campimeter with the fixation point is made to approach the observer. Simultaneously the peripheral objects to be resolved are made to move together on the campimeter surface, in order to approach the fixation point at such a rate that the angle formed by the three points—figures, eye, and fixation point—remains constant. The result of this method is to produce a constantly increasing image on the retina, but always in the same position, so that for any given spot of the retina the acuity is inversely proportional to the size of the image required for a proper resolution.[24]

The A-F and its associated anomalies have all been demonstrated in connection with the translation method only. What would appear with the third method is unknown, because it has not yet been experimentally applied to this particular form of the problem. But the splitting method has been applied.[25]

Before the results of the application of the splitting method can be properly interpreted, the primary purpose of the experiment must be discussed. The aim was to determine whether the A-F were really, as Jaensch and all his followers supposed, a fundamental manifestation of peripheral vision, and not merely a peculiar, and perhaps not readily explicable, function of a particular experimental method, namely the translation method. Especially to Jaensch has the fundamental and universal character of the A-F appeared unquestionable. It assumes such vital importance in his work that it has become the sole basis of his theory of attention

[24] Th. Wertheim, Ueber die indirekte Sehschärfe, *Zsch. f. Psychol.*, 1894, 7, 172 ff. For a fuller discussion of the three possible methods of testing peripheral visual acuity see E. Freeman, *op. cit.*

[25] E. Freeman, *op. cit.*

and of a whole department of psychopathology. A phenomenon for which so much is claimed obviously deserves thorough study. As the only point in question was its fundamentality, which had been assumed on the basis of only one method, it became necessary to apply all other possible methods. This was the intention in the application of the new splitting method, and behind it lay the consideration that only when all conceivable methods had been applied and the A-F found in each, could there be ground for accepting the phenomenon as fundamental. If the A-F failed to appear in one of the three conceivable methods, then it could not be considered as fundamental, nor as anything more than a function of method, and Jaensch's assumption, everywhere implicit in his work and unmarred by the slightest suspicion of any other possibility, would have to be dropped. As a matter of fact, with the splitting method the A-F was eliminated and shown to be no more than a function of method. Such a result was all that could logically have been expected or hoped for, and as such it answered the purpose of the research. But in addition a totally new kind of anomaly appeared gratuitously, and it is with this that the present paper is concerned.

The application of the splitting method brought out an astonishing reversal of the situation as it exists in the A-F of the translation method. Not only did no A-F appear, which was the utmost that could reasonably have been foreseen, but the large constellation revealed an enormous advantage in acuity over the small. Technically this means that in the case of the large constellation the white interval between the black figures which were to be resolved had to be only a fraction, proportionately, of the interval in the small constellation. Put from another point of view, it means that for the large constellation the ultimate retinal image of the white interval was much smaller (as much as one-half) than the image of the interval in the small constellation. Yet both gave the same resolution.

The fact in this situation that is of preëminent importance for the present is that by the employment merely of a different

experimental method, an old anomaly, namely the A-F, was eliminated, and a new one produced, opposite in character to the A-F.

When the attempt was made to discover a basis for this new anomaly in already known facts, it was found that it could perhaps be carried back to the perception of apparent magnitudes, although the anomaly is still retained and still calls for an explanation. Phenomenologically each observer perceived the small constellation as a black figure on a white ground; and the interval by which the objects were resolved as two separate parts belonged to the white ground. But in the case of the large constellation, all of whose dimensions were ten times greater and therefore at a distance ten times as great produced a retinal image identical to that of the small, the black objects, naturally perceived as greater in apparent magnitude, appeared as a ground for the white interval which stood out as figure. There was thus, descriptively or phenomenologically regarded, a difference in the character of the experience in resolving the large and the small constellations; although both experiences depended upon the same retinal image. Somehow the appearance of the interval once as part of the ground and then as figure is conditioned, in some manner not known, by the apparent magnitude of the constellations.[26] This is in itself an important qualitative anomaly quite distinct from the quantitative anomaly of the white intervals with which it is associated. It may be best expressed, perhaps, by the statement that despite identical retinal images there arose with the small constellation the experience of the 'minimum separable,' and with the large the experience of the 'minimum visible.'

It is obvious, therefore, that a new method, in this instance the splitting method, eliminates one anomaly, the A-F, only to introduce another of opposite character, a higher acuity for the large constellation. Bound up with this is the further

[26] It is interesting to note that when a large constellation was selected which phenomenologically appeared of the same apparent magnitude as the small, but geometrically gave a very much smaller retinal image, the difference in acuity favoring the large disappeared and was replaced by a tendency to give the same degree of acuity for both constellations.

anomaly, this time a qualitative one, of a difference in the phenomenological nature of the experience of perceiving the two constellations.

The Measurement of Peripheral Acuity in Instantaneous Illumination

Merely for the sake of further substantiation of his primitive theory of attention, which was his chief concern, Jaensch studied the acuity of the periphery under conditions of instantaneous illumination.[27] His figures, apparatus, and method were precisely those of his experiments under continuous illumination, except that the actual peripheral resolution was made under instantaneous illumination after the figures had been shifted to a tentative position under continuous illumination. If, in the position so selected under continuous illumination, the figures could still be resolved under instantaneous illumination, they were again tentatively shifted further peripherally under continuous illumination and again observed under instantaneous. This process of selecting the position by one and attempting to resolve the figures by the other illumination was repeated until a point sufficiently eccentric was found where the constellation just ceased to be resolved. The crudeness of the method is manifest. It is difficult to say whether the results are to be ascribed to the one illumination or to the other; nor is it at all clear how great a part was played by fatigue, retinal and other, light and dark adaptation, and perhaps other factors. Out of justice to Jaensch it must be said, however, that the method apparently served his purpose and emphasized what he called the rôle of attention, which was after all his principal concern. For this paper Jaensch's theoretical considerations are indifferent. But what is of importance is the objective fact that by a change of method from continuous to instantaneous illumination the relative acuity of the two constellations was found to be different. Now both showed an equal acuity, that is, no A-F appeared.

It has already been shown elsewhere in this paper how

[27] E. R. Jaensch, *op. cit.*

great a difference in results may arise from a simple change in method of experimentation. If, as Jaensch professed to have shown in a rough way, the A-F could be eliminated and conformity with the inferences of geometrical optics could be established by introducing instantaneous illumination, then it seemed advisable to study peripheral acuity by instantaneous illumination more thoroughly and extensively than he had done and with the crudeness and faults of his technique eradicated. But a still more important consideration, a theoretical one, should be taken into account. Whatever Jaensch's results by instantaneous illumination may be, they apply only to the translation method, here somewhat modified to be sure. Part II of this paper has shown that what is true of the translation method is not true of the splitting method, at any rate with continuous illumination. It is therefore legitimate to ask what the results would be by instantaneous illumination coupled with a method other than the translation which Jaensch employed. No a priori answer can be given, because the anomalies already described show how unreliable may be an inference based upon one technique and applied to another.

The answer had to be sought directly by experiment involving the application of instantaneous illumination to figures which lay stationary at a given angle of eccentricity. The upper half of the vertical meridian of the field of vision was selected as in the other experiments. Observation was binocular as before. The position of a given figure or the name of a given letter of the alphabet had to be correctly stated immediately upon instantaneous presentation as an illuminated complex in the dark room. When so correctly stated, it was counted as having been resolved. For convenience this method will be called the *recognition method.* It eliminates not only the juggling with the figures under one illumination and attempting to resolve them under another, as in Jaensch's procedure, but gives us a new and untried set of conditions, namely the coupling of instantaneous illumination with a method other than the translation which was the only one attempted hitherto. The figures are now not to be translated to the point where resolution ceases, but

are to be recognized at a fixed angle of eccentricity, as in the case of the splitting method. A further virtue possessed by the method, one absent in the others, is the presence of an absolute control by the experimenter. He knows the position of the arms of the L and the name of the letters exposed and can, therefore, tell absolutely whether the observer's report is correct. Aside from the introduction of instantaneous illumination this method differs, then, in employing as the measure of acuity, of successful resolutions, the number of correct reports, reports whose correctness can be objectively determined.

Now the question is, what relationship between the large and small constellation will this new method reveal? Three possibilities are conceivable: the A-F will reappear, that is, the small will enjoy a greater acuity; or the large will enjoy a greater acuity, as revealed by the splitting method; or finally, both will possess the same acuity, as physical and geometrical optics dictate. The answer lies in the actual experimental data.

Apparatus. A light box, 50 x 20 x 20 cm, with an electric bulb at one end. The other end open with a grooved frame for the reception of the card in which the desired figure has been cut out and covered over with one or more layers of translucent tissue paper. When the light in the box was burning at the one end a homogeneously illuminated figure appeared in the dark at the other. The bulb circuit (115 volts A.C.) was closed and opened by an electromagnetic power-control relay, which was activated by three dry cells in series giving about four volts. In the dry-cell circuit activating the relay a make-contact was placed vertically over a break-contact, both fastened to a smooth vertical standard. A ball-bearing metal mass with a projecting finger, upon being released, slid down the standard, and with the projecting finger closed the dry-cell circuit at make, and 80 sigma later in the drop opened the circuit at the break contact. (The rate of fall of the ball-bearing mass on the standard was appropriately determined by a tuning fork.) Thus for a period of 80 sigma the dry-cell current was supplied to the relay, which for that same period allowed a flow of 115 volts to the 100-watt daylight bulb in the box.

The light box with the figure at its end could be fastened to any desired height above the light-fixation point upon two rigid vertical gas pipes. The room was dark and the observer dark-adapted before work began.

For the small constellation the eyes were kept, by means of an adjustable plaster of paris chin-rest, on the same level with the light-fixation point and 40 cm distant. For the large constellation they were kept on the same level, but 280 cm distant. The large figure was always seven times greater in linear dimensions than the small. Its vertical distance from the fixation point was likewise seven times greater than that of the small. By this means the retinal image of the large and its point of occupation on the retina (degree of eccentricity) were identical with those of the small. As the

position of the source with relation to figure, the intensity, and the time of illumination were identical for both constellations, the quality, intensity, and duration (as well as form) of the stimulus were all necessarily identical for both constellations. In a word, here were realized all the conditions necessary for a study of the A-F and comparative acuity in general, with the technique of instantaneous illumination cleansed of the defects present in Jaensch's work.

It is to be added that as the bulb remained 50 cm from the illuminated figure, with a plate of ground glass interposed and translucent tissue paper covering the figure cut-out in the card-board, the illumination of the figures was homogeneous.

The first figure employed was L-shaped with equal arms at right angles. It was cut out in a disc which rotated on the card-board. The L could thus be adjusted to point in any direction, unknown in advance to the observer. As a matter of fact, it was exposed in positions differing by 45 degrees in irregular order, and the observer had to report the direction in which the arms lay. If his report were correct it was counted as a successful resolution of the figure. Similarly a series of seven letters of the alphabet was shown in irregular and changing order and had to be named immediately, and not reconstructed in memory or inferred from a partial resolution. When a letter was correctly named, it was counted as a successful resolution. For the L-shaped figure and the letters there was a small series for the 40-cm distance of eyes from fixation point, and an identical large series seven times larger to correspond with the 280-cm distance of eye from fixation point.

The nature of the apparatus and the method of reporting and determining the resolution show the following conditions to have obtained in the experiment. From the dark a luminous figure was projected upon the dark-adapted retina; the observer's resolution had to be absolute and complete, and could be checked by the experimenter from his knowledge of the direction in which the L-shaped figure pointed or from his knowledge of the name of the letter presented; the standard of resolution was the same for both constellations.

The same four observers were used throughout. The L-shaped figure was presented to all observers first at 5 degrees of eccentricity, then at 10, 15, 20, and 25, with five layers of translucent tissue covering the hole in the card-board. If an observer were given the small constellation first at 5 degrees, he got the large first at the next sitting at

10 degrees, alternating in this fashion for the whole series, so that neither constellation was favored by the order of presentation. (As a matter of fact, this precaution was unnecessary, because a trial series in which it was ignored gave the same results.)

The observations of the preceding paragraph were repeated with a 25-watt lamp, all other conditions remaining the same.

With the 100- and 25-watt lamps all the reports for both constellations were correct, without a single error, *i.e.* the resolutions for both constellations were 100 percent. This indicated simply that the intensity of the illumination was still too great and that a lamp of lower wattage would have to be employed.

The whole series was, therefore, repeated with a 15-watt lamp and seven layers of translucent tissue paper over the figure. Now errors in the reports of the position of the L-shaped figure began to come in from all observers, particularly at the larger angles of eccentricity. The failures in resolution sometimes rose as high as 50 percent in both constellations. But whenever failures in resolution appeared they were almost invariably identical in percentage for both constellations. In fact, there was even a high coincidence between the positions of the L-shaped figure that were not resolved in the small and the large constellation. A similar condition existed with the letters. Not only did the percentage of error for both remain the same, but when, for instance, *R* was not resolved, *e.g.* not recognized, in the small, it was also not recognized in the large. The quantitative results are so clear and unequivocal that no advantage is to be derived from tables of data or further particulars. It suffices to conclude that under our particular conditions of instantaneous illumination of only the figure to be resolved, no quantitative discrepancy occurred between the two constellations, and both must be allowed to have been equally well resolved. In this case, then, we have a coincidence with the inference of geometrical optics that identical retinal images, regardless of the size and distance of the external objects, should be resolved equally well in the same retinal spot.

The employment of a series of seven letters of the alphabet, in order to confirm the preceding results, produced nothing different.

To exhaust the possibility that colored light might produce different results, the same series of seven letters was run through at 20 degrees of eccentricity, but instead of white, the illumination was a red produced by a glass filter placed between the bulb and the figure. Then green, yellow, and blue were tried in the same way.[28] But nothing different appeared, the results remaining the same as for the L-shaped figure and letters of the alphabet illuminated by white light.

Recapitulation

The following table recapitulates all the experimentally determined *quantitative* facts of peripheral visual acuity.

Method	Illumination	Ratio between Large and Small Constellation	Results in Relative Acuity	Investigators
1. Translation over blank campimeter.....	continuous white	10 : 1	1. small>large (A-F)	Aubert, Jaensch, etc.
2. do.	do.	2 : 1	2. equality	Dobrowolsky & Gaine
3. Translation over detailed campimeter....	do.	10 : 1	3. equality	Jaensch & Schönheinz, Freeman
4. Splitting on blank campimeter.....	do.	10 : 1	4. large>small	Freeman
5. Illuminated figure in dark room.....	80 sigma white	7 : 1	5. equality	Freeman
6. Illuminated figure in dark room.....	80 sigma, red, green, yellow, blue	7 : 1	6. equality	Freeman

[28] The observers invariably reported the hue of these variously colored letters as yellowish. This was to be expected with our low energies at 20 degrees from the fovea.

(Manuscript received December 15, 1928)

AN EXPERIMENTAL STUDY OF THE PERCEPTION OF OBJECTS

BY G. L. FREEMAN

Psychological Laboratories, Cornell University

The study of perception has a long and involved history. In an exhaustive review of the subject, Rogers [1] has pointed out the persistence of the active and passive views through many centuries of changing emphasis. While current psychology has tended to modify the dualism of these two points of view, both still persist in the analytical and functional accounts of the subject. The analytical method of studying perception has been to take what is assumed to be a representative cross-section of the perceptive experience and to describe the 'content processes' present, together with their mode of integration. The functional method looks to operation. Both of these methods have their limitations. The analytical account cannot assume to have dealt adequately with a performance and its procedure of fractionation tends to create a picture of several independent parts rather than of a single continuous event. In the functional accounts, the free use of logical inference, when based upon a meager amount of observational fact, makes for unreliability.

In the present study we have attempted to escape the limitations of the usual type of experimentation without committing ourselves to certain *a priori* inferences common to most functional accounts. We have accepted only the common observation that perception is a process or operation that has a beginning, course and end, and have set as our problem the study of this integral operation in the perception of objects. This led us to forsake the older type of description in terms of sensational attributes and to approach the problem by way of a method permitting not only a phenomenological description but also a commentary upon the course of the

[1] A. S. Rogers, An analytical study of visual perceptions, *Amer. J. Psychol.*, 1917, 28, 521–538.

perceptive event. Results obtained by the use of this method have been placed in a logical framework intended to show the experiential stages through which the perception passes from the moment the function is initiated to the time when the verbal symbol for the object is realized.

The Experiments

Although objects may involve any one of the sensory avenues, the common preponderance of visual materials influenced our choice of this modality. The use of inkblots as stimulating objects aided the purpose of the experiment by slowing down the stages of perceptive formation. In the first group of experiments the inkblots were shown to the observer [2] with an instruction designed to encourage a full perceptive development. In the second group of experiments the attempt was made to discover something of the relation sustained between the perception of an inkblot as object and the more rapidly developed perceptions of familiar and well-contoured forms.

All experiments were conducted in a dark room.[2] In order to present our objects in the four positions up, down, right and left, we used a large opaque screen, containing four 3-inch square windows placed six feet from the observer. The windows were cut on the quadrants of a circle of 8-inch radius with the center directly in *O*'s line of regard and were covered by shutters under the control of the experimenter.

One experiment provided that some part of the exposed inkblot should attract more attention than the rest of the form. To obtain this without explicit instruction a lamp was devised to throw a narrow light beam of great intensity on the desired portion of the form as it appeared in any of the lighted windows. The lamp consisted of a 200-watt bulb encased in a small tin cylinder mounted on an adjusting standard with a ball-and-socket joint. A round hole of 1/16-inch diameter at one end of the cylinder, over which two

[2] The following served as observers; Professor L. B. Hoisington (H), and graduate students E. R. Moul (M), G. L. Freeman (F), O. D. Anderson (A) and T. Griffin (G). W. James generously acted as experimenter for F. Professor Hoisington generously counseled the author and Professor Bentley helped in preparing the manuscript.

paper cones were superimposed, reduced the illumination to a fine point of light.

In order to confine description more especially to the first phase of perceptive development, a Whipple tachistoscope was used in certain series in front of the right-hand window of the usual exposure apparatus.

In a final experiment, our desire to expose a form gradually led to the abandonment of all the above apparatus. Our purpose was accomplished by projecting forms upon a ground-glass screen placed 13 feet before the observer. Inkblots were made upon cards the size of the projection unit and were covered over by two closely interlocking paper shutters. These shutters could be pulled out to expose the blot or pushed together to cut it out of the field. A more extensive account of how all the above apparatus was employed will be found in the descriptions of the detailed procedures given below.

Nonsense Forms (Inkblots)

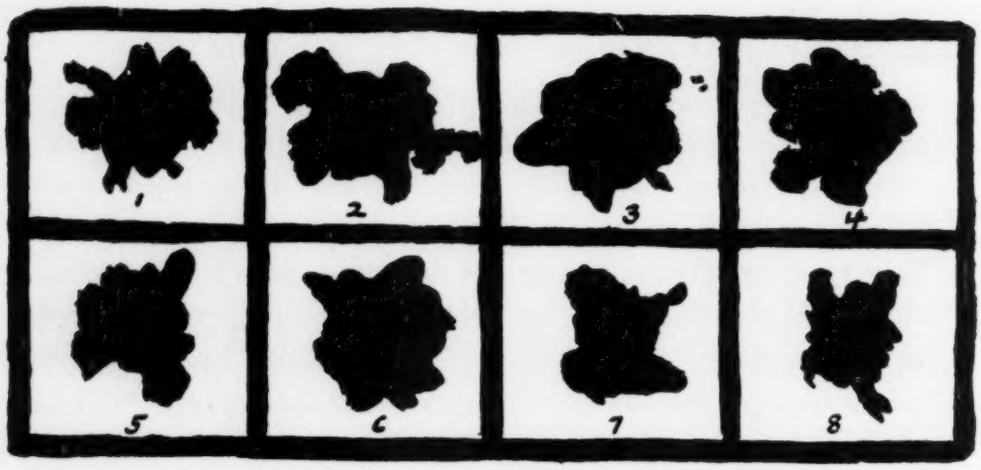
Series 1. By permutation and combination of eight blots and four window openings thirty-two stimuli were obtained. Their position in the series was wholly a matter of random selection. The following instruction was read before every observation.

> I shall show you some nonsense forms with the suggestion that you make each one mean some familiar object. At the 'ready' signal close your eyes and at 'now' open them and look at the form. Report the object meaning and then give a complete account of the total experience at and from the moment the form appeared to the time when the verbal meaning was fully realized.

Series 2. In order to obtain more information upon the initial phase of perceptive development, the series given in I was repeated with only 1.0 sec exposure. While *O*'s eyes were closed, *E* set the apparatus for the desired exposure and turned on the light behind the screen. *O* then opened his eyes and looked at the form for the required period; then the light was turned off. The special instruction was

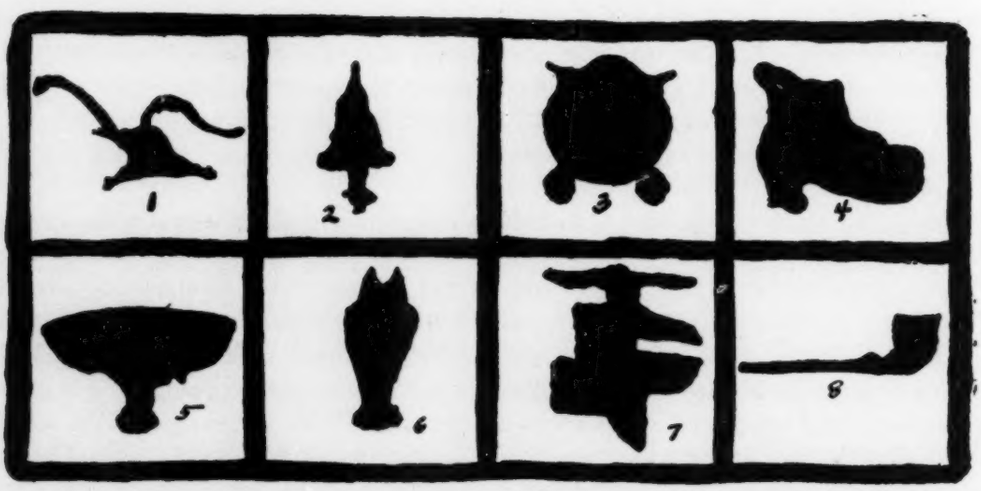
> Confine your account more especially to the moment when you first apprehend the form.

Series 3. In this series we sought to induce a certain new object meaning for a given *O* by way of an advantageous condition. Twenty stimuli which had yielded the most diverse meanings in the first series were selected. A list of the meanings assigned to these blots, together with the reports, enabled the experimenter to obtain a particular kind of object meaning from a given *O* entirely without verbal suggestion. This served as a synthetic check upon the analysis of the two preceding series. The small projection lamp was placed about a foot in front and a trifle to the right of the screen containing the four exposure windows. The experimenter operated this lamp before the screen, all hint of his activities being concealed by a curtain. After making the proper exposure setting, he directed the point of light from the lamp upon the desired portion of the exposed blot. The special instruction to the *O* was as follows:



Nonsense Forms (Ser. i–iv)

Nonsense Forms (Ser. v)



Familiar Forms

FIG. 1

> At the signal 'now' open your eyes and fixate at or near that part of the form which is heightened or accentuated by a small spot of light. Start your search for a common object meaning by viewing the form from the angle of regard indicated by the point of light. When the first object meaning arises, close your eyes and report as you have been accustomed to. If you fail to follow instruction, be sure to state the fact.

Series 4. In this series we wished to observe the influence which changes in the distribution of visual extent had upon object character. The central part of an irregular form was exposed upon a ground glass screen and then, by opening the shutters in front of the form a little farther, still more of the form appeared. The form was thus exposed by degrees until it was entirely uncovered. *O* was set by instruction to put an object meaning upon the form as it changed from time to time, instead of waiting for the entire development to take place before beginning his search. He was asked especially to report upon the shifts in the pattern of experience as the form changed.

Series 5. The purpose of this series was to determine the conditions for the arousal of the initial apprehension of visual extent in the perception of an inkblot as an object. A series of 20 blots, similar to those of preceding series, was exposed tachistoscopically for intervals of about 40σ. The instructions were

> Do not try to develop object meanings from these brief exposures. Set yourself to describe only the initial moment of the form's appearance.

Familiar Forms

Series 1. In this series we sought to confirm the influence of angle of regard and predisposition upon the object meanings attached to familiar visual forms. Eight objects (see Fig. 1) drawn in solid black, spaced about the rotating wheel as were the inkblots of former series, served as stimuli. These forms were tilted from their accustomed positions by shifting them to some other window. The entire series consisted of only sixteen exposures, since each form appeared in its upright and in one of its possible tilted positions. Instruction set the *O* to perceive object meaning in all cases.

Series 2. In this series, 20 silhouette outlines of prehistoric tools, unfamiliar instruments and the like were exposed tachistoscopically for intervals of 0.5 sec. The *O* was instructed to apprehend whatever meaning the forms might have, but was cautioned against putting a makeshift object character upon them.

Results with Nonsense Forms

The method pursued in this study has given us, we believe, sufficient experimental evidence to construct a rough schema of the temporal course of the perceptive function from its initiation by predisposition to its termination in the verbal naming of an object.[3] While such a classification is to a

[3] Several earlier researches contain observations bearing upon this problem. R. M. Ogden (Some experiments on the consciousness of meaning, Titchener Commemorative Volume, 1917, Worcester, Mass., p. 119) mentions that the perception of the meaning of a word presents "three phases." These 'phases' are somewhat similar to the 'levels' of our present account. A. S. Rogers (*ibid.*, p. 546–548) has

certain degree logical, so explicit are the inferences made that our results will be treated entirely in connection with it. This classification aims, first, to show the various levels of perceptive formation which appear when full perceptive development is forced upon nonsense forms and, secondly, to serve as a frame upon which to hang the tags of similar formations found to exist in the more rapidly developed object perceptions of every-day life. With the perception of nonsense forms as objects we were able to make out three well-defined levels of development, each of which revealed upon further analysis secondary formations, as follows;

(1) Level of pre-perceptive determination (molding of extent) [4]

a. Determination of general extent
b. Primary qualification of general extent

(2) Level of perceptive particularity (generation of thingness)

a. Generic particularity
b. Specific particularity

(3) Level of perceptive familiarity (realization of object)

a. Recognition of object
b. Naming of object

The above classification will serve as an outline of our treatment of results got with the use of nonsense forms. Results obtained by the use of familiar forms will also be related to this classification in so far as the experimental results permit.

(1) *Level of pre-perceptive determination.* We have found that the concept of the determining tendency, introduced by Ach,[5] is applicable to the primary level of perceptive development. While the importance of predisposition to perception is generally recognized, this factor cannot be said to be clearly understood or properly assimilated. In the belief

found that the perception of an inkblot as object may pass through as many as five "temporal phases." T. V. Moore (Images and meaning in memory and perception, *Psychol. Monog.*, 1919, 27, 79) has noted that perception presents stages in the "assimilation of sensations to categories of information already possessed by the mind."

[4] The phrases in parentheses indicate the functional significance of the level.

[5] N. Ach, *Über das Willensakt und das Denken*, 1905, 191 ff.

that the imperfect knowledge of the influence of this factor has made the interpretation of much careful experimentation of doubtful worth, we chose to direct special emphasis upon the description of formations of this level. The results indicate two distinctive developments antecedent to formations exhibiting the perceptive character of 'thinghood.'

a. Determination of general extent. By means of special procedures (nonsense forms, Ser. 2, 5) formations of this order were isolated for more precise control and observation. With freedom from eye-movement and a too highly predisposed bias,[6] *O*'s initial apprehension of a visual form was found to fall under one of three general extent categories, viz., *huddled compactness* (h), *determined direction* (d) and *scattered spread* (s). That these general extent determinations are largely predispositional has already been indicated. In the actual work with nonsense forms it was found that all three of the above extent categories might be applied to one and the same inkblot in one and the same position. A study of Table I shows not only the presence of all three extent categories for the same stimulus, but also a number of object meanings given for the same type of apprehended extent. In addition, it indicates that some *O*s are more predisposed towards one type of extent determinant than another; *e.g. G* was the most disposed to regard all the blots as the same kind of thing. 41 percent of his objects fall within the extent category of *huddle*. Contrasted with this, *H*, who prominently exhibited the disposition toward the third type of category, gave only 19 percent of his meanings as emanating from the *huddled* extent. In those cases where the *O*s are more or less agreed upon the general type of extent we may assume that predisposition was more intimately related to the visual excitation due to the less amorphous character of the blots in question.

[6] The *O* is never entirely free from the influence of predisposition at this level of development. It is only when he insists on taking all forms as the same sort of thing, *e.g.*, heads or inkblots, that his bias defeats the small influence of the visual extent.

TABLE I

THE RELATION OF OBJECT REPORTED IN SERIES I TO THE EXTENT DETERMINANTS HUDDLE (h), DIRECTION (d), AND SPREAD (s)

Stim. Obj.	Reported by the Observers H	G	F	M	A	Extent Determinants h	d	s
							Observers	
8*c*	woman	profile	alligator	turkey	man's head	AG	H	MF
6*a*	man with baby	profile	dog's head	cat's head	angel	FMG	HA	
4*b*	2 children	face	wild animal	falling auto	head	GA	H	MF
7*d*	little dog	sunbonnet	poodle dog	dog	sheep	G		AFHM
1*d*	woman and child	profile	excited woman	man running	old woman	G	AMHF	
2*a*	tiger	coat of arms	elephant	ape	horse	G		AFHM
5*b*	woman's head	woman's head	falling bird	falling man	animal head	HGA		MF
2*c*	falling man	teddy bear	dog's face	hen on nest	head	AF	GM	H
3*c*	ship	profile	King Cole	warrior's head	profile	FMGA		H
5*d*	whiskered face	high hat	eagle	airplane	head	HA		GMF
4*a*	dog's head	profile	lion's head	turkey	animal head	GFHA		M
7*b*	flying goose	flying witch	bird	sheep's head		M	G	HF
1*c*	animal head	man riding	animal	angry cat		H		GFM
6*b*	puffer fish	profile	lion's head	maple leaf	head	AGF	H	M
8*d*	bird on nest	dragon	man falling	buzzard	dead fowl		HA	GMF
5*a*	flower	Socrates	horse's head	bouquet	head	AGF	HM	
1*b*	fat squirrel	face	alligator	ballet dancer	profile	AG		FHM
7*c*	goose	ram's head	small poodle	coal bucket	camel's head	AGM		FH
4*d*	turtle	monk's head	dog's head		head	AGF		H
6*c*	stone	profile	man's head	cliff	profile	GHFA	M	
8*a*	falling bird	profile	falling girl	fairy	profile	AG	MF	H
2*d*	animal on pole	bearded face	big-nosed face		one-legged man	GF	AH	
3*b*	woman's head	profile	profile	bouquet	savage's head	GHFM	M	
3*a*	fat man	profile	profile	fan		GMF	H	
8*b*	animal head	turtle	alligator	bird	wolf's head	AH	G	FM
2*b*	face	profile	horse and rider	horse	head	HGA		FM
1*a*	profile	profile	butterfly	fairy	animal head	HAG		MF
4*c*	man in chair	face	woman and load	flower	mother and baby	G	MHFA	
6*d*	animal head	profile	flying bat	man's head	woman's head	GHAM		F
5*c*	head	hand	dog's head	setting hen	cat	HF	M	GA
7*a*	bird	coal pail	man in chair	high hat	coal pail	AF	G	HM
3*d*	woman and baby	profile	indian head	cabbage	profile	MGAF	H	

Reports of extent taken as *huddled compactness*. Obs. *A*(1–8*c*):[7] First flash gave a compact pressury experience, which referred to the visual out there. Obs. *M*(2–6*c*): The projections were less outstanding than the black bulkiness of the form; this seemed to confine the meaning to things having round, bulky form. Obs. *F*(2–3*c*): The first instance gave little more than a feel for the huddle of the extent. Obs. *G*(2–3*c*): The form was first taken as round. Obs. *H*(2–8*a*): The general extent and dimensions of the form came in the first instant. . . . This was largely a bodily experience, compact and unobtrusive, yet referring definitely to the visually given.

Reports of extent taken as *determined directionally*. Obs. *A*(2–5*b*): The first incipient stage can best be characterized by the word *direction*. Obs. *M*(1–7*c*): A directional spread up and down. Obs. *F*(1–1*d*): It came first as 'long' with nothing transcending that. It was a gross sort of feel for the extent, confining eye-movement in the vertical. Obs. *G*(2–7*a*): The form appeared only as a long sort of thing. Obs. *H*(2–2*d*): The first moment gave the major direction in the vertical. There was a positive bodily feel for that long direction which gave a certain determination for eye-movement.

Reports of extent taken as *scattered spread*. Obs. *A*(2–8*d*): At the earliest incipient stage there seemed to be a scatteredness to the form. Obs. *M*(2–7*a*): First a black splotch of irregular contour. Obs. *F*(2–7*d*): There was a feel for a spread-outness of the visual extent in all directions. Obs. *H*(5–5*a*): I did not get, in the exposure, any more than the general shape of the form. The moment gave a big, more or less incoherent, mass which was significant only as a total.

b. The primary qualifications of extent. The formations of this order come as more elaborate developments within the initial determinations and are pre-perceptive in the sense that they look at the form as extent rather than as thing or object. In the initial moment of development, the form was found to appear only as a certain general type of extent. Now, however, it begins to take on internal organization. Its relation to the reacting organism is blocked out crudely as the apprehended extent is qualified in one of three general ways; it is broken up into either (1) near and far, (2) right and left, or (3) up and down. In any case one portion of the extent receives major emphasis to the neglect of the other part. The habitual influence of this order of determinant is easily shown with reference to the perception of the visual scene. The horizon line serves as a point of division below which the scene seems more substantial and emphatic. We habitually think of various objects in the scene as being to

[7] The first number in the parentheses preceding *O*'s report indicates the series from which it is taken. The second numeral indicates the inkblot used. The letter following refers to the window at which it was exposed. See Fig. 1 for facsimiles of forms used.

the right or to the left of us, while the characteristic of a well-balanced painting is a major emphasis upon one side. The qualification of the extent of a form is just as compelling as for the visual scene. If one will consider one's perception of the duck-rabbit figure or of the Necker cube, one will see that what changes the perception is, in reality, a different 'way of taking' the figure. The duck-rabbit figure falls under the right-left qualification and, when looked at from the right, the right side receives major emphasis; looked at from the left, what was formerly obscure becomes the significant part of the form. A like description holds for the changing character of the Necker cube; only now the extent is qualified in the up-down direction.

With reference to our own experiments it should not be difficult to note that what underlies a shift in the object meaning of a blot, occasioned by tilting it to a new position, is a change in either the qualifications of the extent or the emphasis upon one portion of it. This same factor is at work when the position of the blot is kept constant while the 'figurative' angle of regard is changed in relation to it. Looking at a form one way occasions a differently organized extent from that obtained by looking at it from some other angle.

One of the prime conditions for the primary qualification of extent is the presence of eye-movement.[8] The reports of our *O*s, which are confirmed by the synthetic experiment (Ser. 3), indicate that the initial determination is carried to greater elaboration by the movement of the eyes made in response to the stimulus. The presence of controlled eye-movement in the initial level of perceptive development cannot be overestimated, since the more highly patterned sensory experience about the eyes marks the start of the specific focusing of detail, which is characteristic of formations of the next order.

To test more precisely the influence of the primary qualifications of extent upon the object meanings given for the several forms, a procedure was devised for producing such

[8] Cf. W. Wundt, *Grundzüge der physiologischen Psychologie*, 6th ed., 1910, vol. 2, 576–580.

tendencies synthetically. By casting a small beam of light from the projection lamp upon a portion of the form and then instructing the *O* to look at the form from this angle, an object meaning could be obtained very similar to that given by some other *O* when he had looked at the form from this same point of vantage. Thus, when the light was shifted back and forth across the right side of form 8*a*, *H* reported 'profile' instead of his former meaning (falling bird). On the other hand, by emphasizing the up-down direction of the form, *G* reported 'bird' instead of his former meaning (profile). Where the *O* was able to obey instruction,[9] the following percentage of his meanings were definitely conditioned by the 'synthetically produced' qualifications of the extent: *G* 85.7; *A* 93.3; *M* 81.8; *F* 93.3; *H* 94.5.

Reports of primary qualification of extent. Obs. *A*(1–6*a*): From this non-specific extent, the form was now organized about a particular line of regard from top to bottom. . . . The top seemed more emphatic. Obs. *M*(1–5*b*): There was a change in the pattern of experience as the balance of the form was given, with accompanying eye-movement to confirm the suggestion. Obs. *F*(1–8*d*): Out of the 'scatteredness' of the form arose a major line of reference, about which the form was organized. Obs. *H*(1–2*a*): The whole mold of extent was now cast; as I looked from now on fixation was directed. (3–8*c*): The form was seen from the angle indicated by the light and shaped itself in harmony with this way of taking the thing. Obs. *G*(3–7*b*). The more vivid portion of the form seemed to be more important. When I had my meaning, I found that I was looking particularly at this side of the form.

(2) *Level of perceptive particularity.* On the preceding level, the form appeared as a mere existence of visual extent. Almost as soon as its primary qualifications are realized, however, there comes the awareness that one is looking at a 'thing.' The contour is clearer, while some projection or point in the form becomes significant for meaning. The form is now seen as having a 'focus' and a 'background.'[10] The

[9] Those cases where *O* did not follow instruction are due without doubt to the inability of the 'synthetically produced' qualification to cut across a counter predisposition. A careful study of the reports of these failures has indicated that these blots were somehow related more intimately to the past experience of the *O*. It is very likely that familiar forms are habitually seen in a favored 'extent' mold. This question belongs properly to a later section.

[10] These terms are not to be confused with *Gestalt* 'figure' and 'ground,' to which they sustain a very interesting but far from identical relation. 'Focus' and 'background' are developments within 'figure,' but contribute jointly to the meaning of the 'figure' as do the grosser *Gestalt* terms.

'background' refers to the general-form unity and is very like the feel of the general extent of the form on Level 1. The focus of the pattern arises with the noting and fitting of detail within the form unity. During the organization of experience at this level, it is possible to obtain two different formations. The first may be characterized by the catch phrase, 'a something,' and the second by 'that thing.'[11] Usually a 'something' becomes a 'thing,' although we had occasional reports of experiences which developed no further than the 'something' stage. To the 'something' formation we have given the function of generating generic particularity as contrasted with the specific particularity of the 'thing' meaning.

a. Generic particularity. Although the reports of our *O*s were confined almost solely to the coming of the 'thing' meaning, they sometimes gave hints of its antecedent and generic form. Occasionally, in getting the primary qualification of the visual extent, *O* reported a stoppage of eye-movement. (*E.g.* Obs. *H.* The halt seemed to mean that this projection was significant. The pattern now meant some kind or class of beast perhaps—only it was never as specific as beast—just an animate something.) During this period, the angle of regard probably becomes connected with some projection in the emphasized part of the visual extent. This projection, not at first apprehended apart from the emphasized portion, now serves as a point for specific organization. As this projection is noted as significant, the general type or class of thing is likely to appear. This focal detail is still set off from the general unity of the form and it remains for the next development to produce an adequate fitting. The chief characteristic of this formation, therefore, appears to be the noting of a detail or projection as focally significant.

b. Specific particularity. The pattern of this order of formation is more highly organized than the preceding. While it exhibits the same perceptive character of focus and

[11] The term 'thing' is used in a rather restricted sense. It does not include objects, whose meaning is that of familiar particulars. Thus a strange appliance would remain a 'thing' in the above sense only if one failed to place it in past experience.

background as did its generic formation, the focus has become highly specific and more definitely integrated with the general-form unity carried by the background. The noted detail now fits with the total form character to produce the meaning of a 'thing.'

In Series 4 the attempt was made to get at this process of 'fitting' by experimental means. In connection with the changing form, it was found that the experiential qualities that carried the form value of a focal detail were only such as could enter into a totality with the more general pattern of qualities that carried the significance of the general extent. While the changing forms used in this series brought changes in the apprehension of the general extent, the same projection of the stimulus might remain experientially focal. In these cases it was found that this projection did not keep its original significance, for, whenever there occurred a reapprehension of the general extent, a kaleidoscopic rearrangement in the significance of the focal projection also followed; that is, the detail was revalued in agreement with its new background. Thus the projection which had formerly stood for the nose of a compact form became the head of an animal when the general extent was reapprehended as 'scattered.' It becomes clear from this that a certain background will admit only certain focal details. After a projection is noted, it must take on a meaningful significance in conformity with what is already given. Here we get a glimpse at the working of a law of experiential connection on what we may term a very primitive level; 'focus' and 'background' bound up in a structure-functional totality. With their fitting, a particular configuration flashes forth, in which the two factors have become functionally interdependent.

Reports. Obs. *H*(1–1*b*): But this 'tail' detail came specifically in terms of mouth-throat experience, which, however, had its immediate reflection in the total form pattern, fitting with it. Obs. *A*(1–2*d*): The form still seemed to require a good bit of organization; a fitting of the noted detail with the more general form character. Obs. *G*(1–8*d*): This projection stood out clearly, and was in meaningful relation with the form taken as a total. Obs. *F*(4–7): First a directional dominance to the extent, then presently a reapprehension of the form as compact. I noted that with this shift in the general extent, what had formerly been a head now became a nose. Obs. *M*(4–4)

Presently the new aspect of the stimulus caused the former meaning of the general form character to go; but the same detail still retained its significance; only it *wasn't* the 'same' detail.

(3) *Level of perceptive familiarity.* The moment a specific configuration is formed recognition usually follows, accompanied by the marked shift in the character of perceptive formation. There is a passage from the strain set that eventuated in all the formations of the preceding levels, where the meaning of search and anticipation was very apparent, to a stage where the specific object meaning is dominant, if not overwhelming. The two formations of this level give us our objects, our world of familiars, and mark the most highly perfected stage of the perceptive function. The first formation is one in which the recognition of the form as object is realized. This is quickly followed by the verbal naming of the object recognized.

a. Recognition of object. The realization of a familiar object is seemingly carried by an emphatic attitude that is affectively toned. These habitual attitudes mean 'that thing' in terms of a usual reaction. The experiential shift to glow and weak pressure carries as yet no implication of the verbal, and is best described in the terms of Obs. *H* "I know what you are." It appears as if the stimulus and the exciting strain which carries the task to perceive had completed their task as a ready-to-hand pattern flashes forth. The change in outlook is as complete as the change in experience. The shift is from seeing some object in the visually presented to seeing the visually presented *as* an object. It is at this level of development that we find the meaning originally carried by the bodily qualities to have become almost completely replaced by the visually given.

Reports. Obs. *F*(3–8*c*): Bodily experience seems to have dropped out entirely. The visual form appeared to carry all the meaning of the kinæsthesis so prominent in the preceding moment. Obs. *A*(1–7*c*): The form was now a meaningful object, realized tri-dimensionally. Obs. *M*(3–6*a*): As the meaning of object attached to the visual form, I noted a brightening in experience. Obs. *G*(1–2*a*): There came a release from the close examination of the form. Obs. *H*(1–4*a*): Before it was as if I had been in more intimate contact with the form. Now I saw it from a little 'distance.' Experience was more homogeneous and the object meaning was the dominant thing. The stimulus now appeared as a visual object instead of being simply an object of vision.

b. Naming of object. The naming process consists in the fitting of an appropriate word to stand for the recognized object. All development, up to this point, has been preverbal. Now, however, *O* generally finds the name of an object 'on the tip of his tongue.' Just how the verbal emerges is not to be answered by our study, since reports of the process are almost entirely lacking. The formation itself is clear-cut enough to warrant a separation from the formation which recognizes a 'thing' as 'object.' Its adequate description offers a problem for the future.

Results with Familiar Forms

Our experiments with familiar forms confirm the significance of our work with inkblots. It will be recalled that with the latter the bodily reactions made in the past to objects of vision become very useful (to the organism) in forcing an object meaning upon these forms. The first two levels of development seemed to depend upon kinæsthetic factors as much as, if not more than, upon visual. The gradual elaboration of perceptive data was traced from the moment the function was initiated to the level of perceptive familiarity. The shift in experience at this level seemingly furnishes the cue to what happens in our perception of familiar forms as objects. The significance originally carried by the kinæsthetic processes tends to be transferred to the visual core of the experience.

We have found many confirmations of the essential influence of 'predisposed regard' in our experiments with familiar forms. While the conclusion that every type of familiar form has come to be qualified in some particular way is not warranted by our present state of knowledge, results obtained in the tilting of familiar forms go to confirm the inference. The tilting experiment built logically on the argument that, if familiar forms have certain favored angles of regard or are qualified by predispositional factors, their original meaning may be changed by tilting these forms into other position. The obvious difficulty was to reduce the influence of predisposition to a minimum, since we are

ordinarily able to apprehend an object as easily in its tilted as in its normal position. This difficulty was partially overcome in this experiment by the choice of forms which would, in their tilted positions, suggest another object more readily than the original. (The forms used in this experiment are shown in Fig. 1.) The table below gives the various meanings reported for these forms in their normal and tilted positions.

TABLE II

SHIFTS IN OBJECT CHARACTER OCCASIONED BY THE TILTING OF FAMILIAR FORMS FROM THEIR USUAL POSITION

Stim. Obj.	Exposed at	Meanings reported by *O*'s H	F	M	A
1	*a*	plow	plow	plow	plow
	c	brownie	long-legged bird	ostrich	long-legged bird
2	*a*	pine tree	pine	pine	pine
	c	dagger	spear	umbrella	arrowhead
3	*a*	iron kettle	kettle	kettle	jardiniere
	c	fat mouse	shield	cat's head	bear's head
4	*a*	shoe	shoe	shoe	shoe
	c	animal head	hound's head	animal head	animal head
5	*c*	lamp shade	dish cover	dish cover	dish cover
	d	airplane	profile	profile	airplane
6	*a*	cat	vase	gloved fist	fish
	d	fish	fish	fish	fish
7	*a*	man with baskets	vise	mechanical figure	mechanical toy
	b	vise	vise	vise	vise
8	*a*	pipe	pipe	pipe	pipe
	c	pistol	pistol	pistol	pistol

Reports taken in connection with the tilting of familiar forms present several interesting facts. The general distribution of the extent seemed to be immediately suggestive of some angle of regard, differing as the form was tilted. The object meaning seemed to 'flash forth,' but as one *O* put it "In that instant I knew I was looking at the form in a particular way." Very often some one detail was found to be significant for the particular meaning given. It was also noted that a detail which was significant for one position of the form was quite unnoticed when the form was tilted. This is easily demonstrated with reference to the pistol pipe form (Fig. 1, Familiar Forms, 8). When in position *a*, one looks toward the mass on the right, which stands for the bowl of the pipe. In the inverted position *c*, one looks

toward the thin part of the form and the significant detail seems to be the formerly unnoticed bump in the bend of the form.

Reports. Obs. *H:* The meaning flashed in as I rounded this curve and looked toward the end of what became the barrel. Obs. *F:* The first instant gave a vertical extent of black that developed from the bottom up. By the time I had reached the top it had come to mean 'tree.' Obs. *M:* That thing at the top seemed to be most bound up with the way I took the form. Obs. *A:* The moment it came as shoe I was aware that I was looking at the form in a particular way.

In our experiment with tachistoscopic exposure, additional confirmation of the work with nonsense forms was obtained. When silhouettes of unfamiliar instruments and objects were shown for a period of 0.5 sec, the *O* usually reported the kind of formation typified in the second level of perceptive development. The forms generally meant that the visually given was a 'thing,' yet not a 'familiar.' Further, it happened that when a perfectly familiar form was injected into this series, the *O*, taken off guard, reported it only as a 'thing' whose object character he was in no way sure of.

Reports. Obs. *H:* There was a halt at the top, and then some inner set to sweep with the eyes. This instant is quite similar to a stage in the perception of the nonsense blots. Obs. *F:* Meant a thing of a particular type, but I couldn't say what the type was. Obs. *M:* In these I have a notion of the sort of thing they are but I can't place them. Obs. *A:* A particular kind of instrument; but I can't guess its usage.

Summary

The results of our experiments emphasize the importance of bodily reactions in the determination of the meaning of visual forms. This indicates that the organism is actively engaged in the perception of objects, rather than passively receptive to an environmental agent; and that the part played by experience is one of providing the context or meaning of what the organism is doing. Our method of combining inspection and commentary has given us a descriptive picture of the progressive course of the perceptive function. The perception of a nonsense form as object passes through three well-defined stages or levels of development. On the first level is determined the general extent of the form. This is predispositional in character. The second level serves to

generate thingness and the third level recognizes the thing as object. The perception of familiar forms corresponds quite closely to this third level; although the two preceding are often in evidence but highly telescoped. The significance of the bodily reactions of the first two levels tends to become replaced by the visually given in these forms.

These experiments emphasize a new development in the perception of objects which merits the consideration of future investigators. Aside from the emergence of 'figure' from 'ground,' so emphatically heralded by the adherents of *Gestalt*, a very significant development occurs within the 'figure' itself. A part becomes focal while the general shape serves as background. Both 'focus' and 'background' mutually contribute to the context of the figure and are bound together in a functional totality.

(Manuscript received January 18, 1929)

An Instrument for Summating the Oscillations of a Line

BY CLARK L. HULL

Yale University

There exist a number of special instruments for measuring various types of irregularities. Perhaps the best known of these is the planimeter. One may trace with the moving point of this instrument the outline of any small plane surface, no matter how irregular the outline may be, and at the conclusion read off at once the area. For some time the writer has felt the need of a corresponding instrument for measuring and summating the vertical oscillations of horizontally moving lines. Such lines are very common among kymograph tracings. As examples of behavior yielding more or less irregularly oscillating lines, there may be mentioned breathing, pulse, blood pressure, body volume, the galvanic skin reaction, and various forms of bodily tremor. The necessity of such an instrument for the satisfactory conduct of several research projects in the author's laboratory finally brought about its design and construction. Because of the function which it performs the instrument is called a *linear oscillometer*. It is shown in Plate I as it appears in use.

The device consists of a pair of rails upon which is mounted the measuring instrument proper. The rails are 8 in apart and extend the length of the base plate (*A*). This plate is of hard, non-warping material, 3 ft long, 1 ft wide, and ¼ in thick. The rails are made of ½-in angle iron, one side of the angle being screwed firmly to the base plate. The upper surface of one of the rails is machined flat while that of the other (*B*) is milled to the form of an inverted V. Placed between the rails is a board (*D*) of soft spongy pine with its upper surface flush with the tops of the rails. A paper record bearing tracings to be measured is easily attached to this wood by means of thumb tacks. Such a record in position for measurement is shown at *C*.

The measuring instrument itself takes the form of a light metal car. The framework (*E*) of this car is made of brass tubing ½ in square. The frame has an outside measurement of 7½ in by 12 in, the long dimension running parallel with the direction of movement. The car is supported by three small wheels. Two of the wheels (*H*, *H'*) are grooved to fit the V-shaped rail and are attached respectively to the front and the rear of the frame. The remaining wheel has a smooth face and is attached to the frame on the opposite side about midway between front and rear.

Across the middle of the frame is a solid metal piece (*F*) which is 1½ in wide by ½ in thick. Upon the center of this crosspiece is firmly mounted a vertical cylindrical metal tube $\frac{5}{16}$ in. in diameter and 4½ in high. This tube is carefully bushed at top and bottom so as to receive a steel shaft $\frac{3}{16}$ in. in diameter. The shaft passes down through the crosspiece supporting the tube, and immediately beneath the light flanged pulley (*G*) is attached. To the other end of the shaft which projects from the upper extremity of the tube is attached the light L-shaped arm (*K*). Supported by appropriate iron rings on the outside of the tube are the free-moving graduated aluminum wheels, *W* and *W'*. A snugly fitting rubber band is stretched around the circumference of each wheel like a tire.

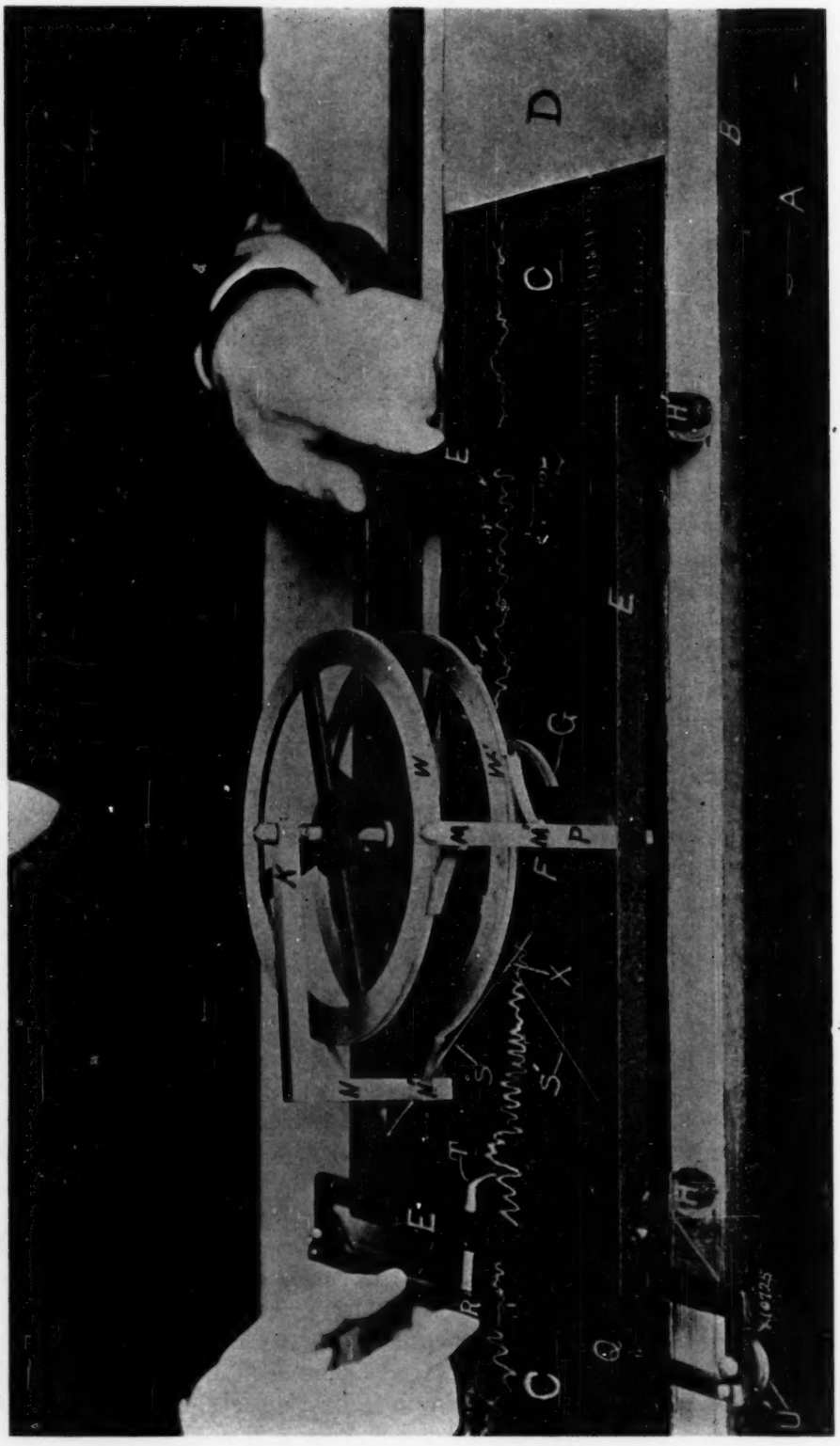


PLATE I. The linear oscillometer

Supported at the front of the car by suitable metal pieces is the ¼ in square steel bar (*Q*). Sliding freely on this bar is (*R*) a piece of square brass tubing 2½ in long. Attached to the sliding tube (*R*) is the pointer (*T*). On the lower side at each end of this tube is soldered a small ring. To these rings are attached securely the respective ends of a piece of piano wire .009 in. in diameter. From the tube the two ends of the wire extend in opposite directions to the respective ends of the bar (*Q*) where they pass around small flanged pulleys at *U* and *U'*. From these pulleys the wire passes backward and around the pulley (*G*) appearing as thin white lines at *S* and *S'* and crossing at *X*. Owing to the limitations on its range of movement, there is one point on *G* from which the wire would never leave the groove, even if unrestrained. To prevent any possible slipping of the wire when it is driving the pulley, the former is firmly attached to the groove at this point. The wire is drawn rather tightly so that when plucked it gives forth a clearly audible tone.

When in use the instrument is grasped by the operator's hands as shown in the plate, the right hand manipulating the sliding tube (*R*). By sliding *R* back and forth and at the same time gradually moving the car on its wheels along the tracks toward the operator's left, pointer *T* may be made to trace in detail any vertically oscillating line such as that shown. As *R* moves forward and back, the stretched wire attached to it produces a rotary movement in pulley *G*. This, in turn, imparts a corresponding movement to arm (*K*) which is attached to the same shaft.

To the vertical portion of arm (*K*) are attached two spring pawls (*N* and *N'*). These pawls have sharp, blade-like ends which press respectively upon the circumferences of graduated wheels (*W* and *W'*). The pawls face in opposite directions. A stationary post (*P*) supports two similar pawls which also face in opposite directions. When *R* is moved in a direction away from the operator, arm *K* is driven in a clockwise direction. When this takes place, pawl *N* bites into the rubber tire of *W*, imparting to the latter a corresponding clockwise motion. As this takes place, the tire slides freely beneath a stationary pawl (*M*). When, however, *R* reverses its direction and moves toward the operator, the arm (*K*) is driven in a counter-clockwise direction. In this latter case pawl *M* bites into the rubber tire of *W*, holding the wheel stationary while pawl *N* is dragged backward. Wheel *W'* is actuated in an analogous manner except in the opposite direction. Thus each wheel is always held stationary while the other wheel is responding to a movement of *R* (and *T*).

W registers cumulatively only movements of the tracer in a direction *away* from the operator; while *W'* registers cumulatively only movements of the tracer *toward* the operator. The sum of the cumulative movements registered on the two wheels indicates the total amount of forward and backward movement made by *R* and *T* in tracing a vertically oscillating line. The upper surfaces of *W* and *W'* are alike graduated in degrees of arc but are numbered in opposite directions. One degree corresponds to a movement by *R* of approximately 1/40-in. By giving pulley *G* a slightly different size, degrees on *W* and *W'* could be made to correspond to movements by *T* of exactly one millimeter.